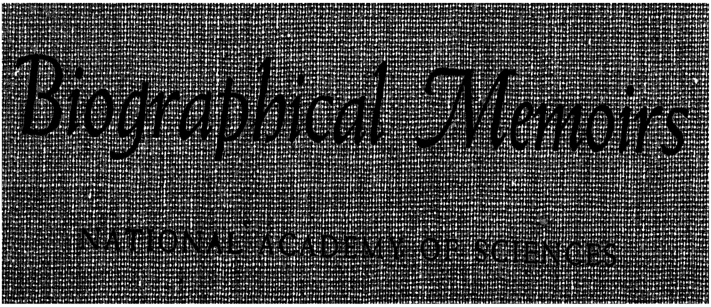

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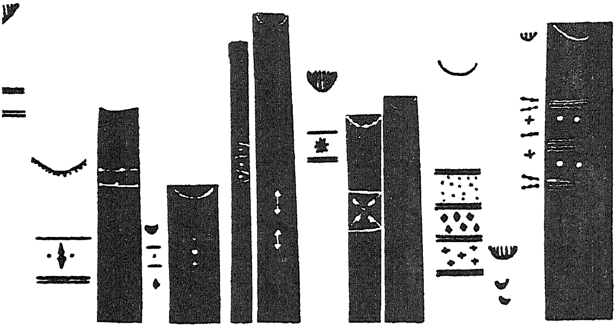

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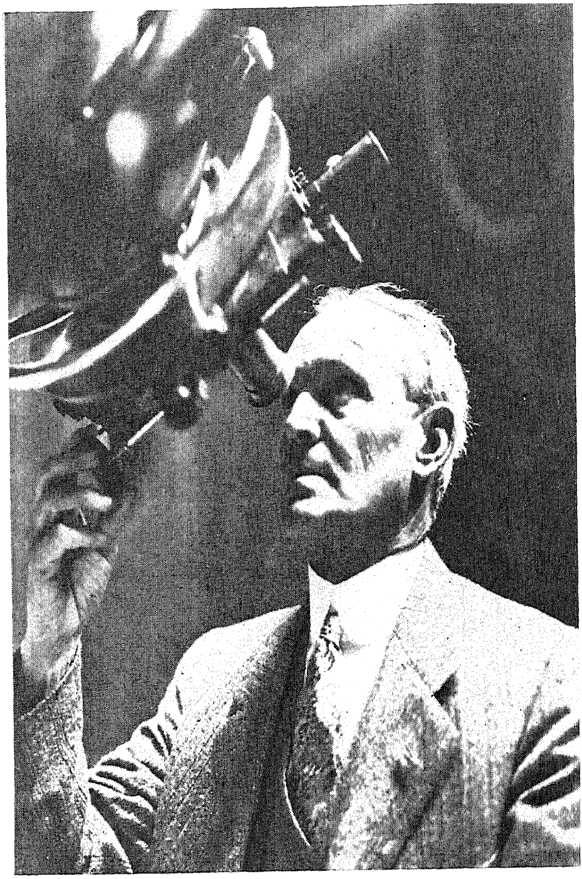

Robert G. Aitken

ROBERT GRANT AITKEN

December 31, 1864—October 29, 1951

BY WILLEM H. VAN DEN BOS

ROBERT GRANT AITKEN was born on December 31, 1864, in Jackson, California, and died on October 29, 1951, in Berkeley, California. His father, Robert Aitken, came to America from Scotland and his mother, Wilhelmina Depinau, was the daughter of German immigrants.

His early education followed classical rather than scientific lines, as his mother wished him to enter the ministry. In 1880 he entered the Oakland High School and in 1883 Williams College, still with the ministry in view. However, he also took courses in biology and astronomy and did some work in the observatory under Truman Safford. He graduated in 1887, but as a result of his reading he felt —though he remained a deeply religious man to the end of his days —that he could not become a preacher of the orthodox, doctrinaire theology of the day. He accepted a position as house master in the Hopkins Academy, Oakland.

In 1888 Aitken married his high school classmate, Jessie L. Thomas, and accepted a position as head teacher in Livermore College, where he stayed until 1891, when he was appointed professor of mathematics in the (then) University of the Pacific. Here he found a little observatory, equipped with a good 6-inch Clark refractor and a small reversible transit. He made the acquaintance of Barnard and Holden of the Lick Observatory, and at last his future career began to take shape.

In June, 1894, he spent a fortnight on Mount Hamilton as Holden's guest and a year later repeated his visit, this time accompanied by his family. He remained at Lick for the next forty years, retiring in June, 1935. Starting as Assistant Astronomer, Aitken was promoted to Astronomer in 1907, Associate Director in 1923, and Director in 1930.

At first his time was devoted to all kinds of routine work and to the observation of comets, asteroids, satellites, double stars, and orbit computation, but double stars took an ever larger part of his time and it is as a double star astronomer—and assuredly as one of the greatest of them—that Aitken will be remembered.

When Aitken started his career at Lick, the dominant figure in double star astronomy was Sherburne Wesley Burnham. Burnham—like Dawes and Dembowski and many other well-known double star observers, an amateur astronomer—initiated the second era of double star astronomy, which began with the last quarter of the nineteenth century. After the pioneer work of the Herschels and Struves, the mistaken opinion had taken hold that, as far as finding new double stars was concerned, the skies were exhausted. Burnham soon showed that, even with a 6-inch refractor, many double stars remained to be found. When he had the opportunity of using telescopes of greater power, culminating in the Lick 36-and Yerkes 40-inch refractors, his discoveries continued unabated, and it became clear that the number of double stars as yet undiscovered but within the grasp of such powerful instruments considerably exceeded the known pairs.

Aitken was well aware of this; also, he was convinced that the prerequisite for statistical investigations was a systematic survey, in which all stars down to a certain magnitude were to be inspected for duplicity, using a powerful modern telescope. Consequently he started such a survey in 1899, his colleague Hussey joining forces with him soon afterwards. All stars given in the Bonner Durchmusterung as not fainter than 9.0 (Aitken) or 9.1 (Hussey), down to 14 degrees southern declination or, during the more favorable season, 22 degrees, were to be tested. Some of the searches were made with the (excellent) 12-inch Lick refractor, but the great majority with the 36-inch.

When Hussey left Lick in 1905, Aitken took over his zones and finished the survey in 1915. It resulted in the discovery of about 4,400 new pairs, of which more than 3,000 were Aitken's. Nearly all of them have separations under 5″ and many, though by no means all, are very close and difficult pairs to measure.

Even this great survey has not exhausted the northern skies; a considerable number of new pairs has been discovered since its completion, quite apart from those fainter than the ninth magnitude. No survey, no matter how carefully done, can ever be exhaustive: there will always be pairs escaping discovery because their separation happens to be too small at the time of inspection, though well within the telescope's grasp at other times, or for other reasons.

Nevertheless, this type of survey is the only one capable of answering a number of questions of a statistical nature and Aitken, after its completion, embarked on some statistical investigations, the results of which he published in his well-known textbook *The Binary Stars,* the first edition of which appeared in 1918, and a revised edition in 1935. He was, however, first and foremost an outstanding observer and his major contributions to his chosen field, apart from the survey, consist of his careful and accurate measurements, kept up right through his active career, of thousands of close and difficult pairs, his own discoveries as well as others. Numerous orbits were computed when, to Aitken's cautious mind, the data of observation seemed to justify the attempt. Though in the first rank as a double star discoverer, Aitken never forgot that discovery is only the first step in a double star's history and that the mere fact whether a particular star is or is not double is of comparatively small importance; discovery must be followed up by regular remeasurement, covering decades if not centuries, so that the motion may be found and ultimately the orbit computed. It is only after this stage has been reached that the pair can supply information of great value to astronomical science, such as a knowledge of stellar masses—data of fundamental importance in stellar research. The binary stars with known orbits also supply the observational material for studies of the statistical distribution of their periods of revolution, eccentricity of the orbit, semi axes major, orientation in space of orbit planes and of major axes with respect to the galactic plane, etc. Aitken deals with all these aspects of double star astronomy in *The Binary Stars,* in addition to chapters on its historical development, methods of observation and orbit computation, spectroscopic and eclipsing binaries, hypotheses on the origin of the binary and multiple stars, etc.

In 1932, shortly before the end of his active career as a double star observer, Aitken published his magnum opus: *New General Catalogue of Double Stars within 120° of the North Pole.*

In the course of the nineteenth century a vast amount of observational material on double stars and multiple stars in the form of measurements, orbits, and theoretical studies had been accumulated. This information was scattered over a large number of more or less accessible publications and periodicals, so that the task of collecting a complete set of data on a particular object became more and more difficult. The need was felt of a compact and reliable source of reference which would spare the investigator the burden of hunting blindly through a large astronomical library.

It was Burnham who supplied this by the publication, in 1906, of his *General Catalogue of Double Stars within 121° of the North Pole,* while Innes, at the Cape Observatory, had covered the southern hemisphere by his *Reference Catalogue,* published in 1899. These works were of inestimable value to any astronomer requiring information on double star matters, but they gradually became out of date and, after the lapse of another quarter of a century, the need for a supplement or revision became apparent. Aitken's friend and colleague, Eric Doolittle, had taken over Burnham's task of compilation and had kept a card catalogue up to date.

Shortly before Doolittle's death in 1920, he handed over his cards to Aitken, who brought them up to date and used them in the preparation of his *New General Catalogue,* known to every astronomer as the ADS. This is complete to 1927 and supplies, when combined with Burnham's BDS, all the information on double stars and multiple stars up to that year which can reasonably be asked for. At about the same time, Innes, at the Union Observatory, Johannesburg, published his SDS, a loose-leaf catalogue covering the region from 19 degrees southern declination to the South Pole.

At the present time the need for a further revision is once more felt and the publication of a reference catalogue covering the whole sky and based on the two card catalogues kept at Lick and Johannesburg is contemplated. However, when such a publication materializes, it will in no way render the ADS obsolete, just as the publication of the ADS did not make the BDS obsolete. The ADS is, and will remain, a lasting monument to Aitken's life work. Even a superficial study of it reveals the quantity and quality of Aitken's own contribution as a double star observer.

Aitken received many honors, such as Sc.D. from the University of the Pacific in 1903, Williams College in 1917, and the University of Arizona in 1923, LL.D. from the University of California (Los Angeles) in 1935, the Lalande Gold Medal from the French Academy of Sciences in 1906, the Bruce Gold Medal from the Astronomical Society of the Pacific in 1926, the Royal Astronomical Society's Gold Medal in 1932. In the same year, 1932, he delivered the Darwin Lecture to the Royal Astronomical Society, taking as his subject "What we know about double stars," a masterly exposition which should be carefully studied by anyone interested in double star problems.

Aitken was a member of and held official positions in several learned societies: the Astronomical Society of the Pacific, of which he was President in 1898 and 1915, and Editor of Publications from 1897 to 1908 and from 1911 until his death, Secretary and member of various committees for many years; the American Astronomical Society, of which he was Vice-President from 1929 to 1931 and President from 1937 to 1940; the American Philosophical Society; the National Academy of Sciences, in which he was chairman of its section of astronomy from 1929 to 1932; the American Association for the Advancement of Science, in which he was President of the Pacific Division in 1925, Vice-President and chairman of Section D in 1926; the Royal Astronomical Society, of which he was an associate; the British Astronomical Association; the Rittenhouse Astronomical Society; Phi Beta Kappa; and Sigma Xi.

When, after the first World War, the International Astronomical Union came into being in 1919 and organized its various commissions, it was a foregone conclusion that Aitken would become the first President of Commision 26, Double Stars. He was succeeded in this function by Hertzsprung in 1928, but remained a member of the Commission until his death. After his retirement he was elected Honorary President of the Commission, a gesture by his colleagues which the Grand Old Man of double star astronomy greatly appreciated.

In infancy Aitken's health was rather delicate as a result of a severe attack of pneumonia, and he did not go to school until he was nine years old but in his later years he had a strong constitution, which enabled him to work as hard as he did—long nights of visual observing with a large telescope are a strenuous form of sport. Even in old age he recovered from a serious illness as well as from the effects of a street accident when, as a result of his deafness, he was run over by an automobile in the streets of Berkeley.

His deafness was an affliction of long standing, although with the help of a hearing aid he was able to follow a lecture and to enjoy a concert. He was very fond of good music and, not being a performer, obtained great satisfaction from his player-piano.

The death of Mrs. Aitken in 1943, a few years after they retired from Mount Hamilton to Berkeley, affected him greatly, but he obtained strength from his conviction that the separation would be temporary and short. He took a deep interest in the welfare of his children—three sons and a daughter survive him—, his eight grandchildren, and nine great-grandchildren, and was happy that many of them lived near enough to him so that he could see them often.

Aitken was not in the least like the scientist of fiction in his ivory tower; he took a deep and active interest in civic matters and in the popularization of astronomy, to which he devoted even more of his time after retirement. He was in demand as a lecturer and a regular contributor of popular articles on astronomical subjects in the Leaflets of the Astronomical Society of the Pacific.

KEY TO ABBREVIATIONS

A.J. = Astronomical Journal
A.N. = Astronomische Nachrichten
A.S.P.L. = Astronomical Society of the Pacific Leaflets
L.O.B. = Lick Observatory Bulletin
L.O.P. = Lick Observatory Publications
M.N. = Monthly Notices of the Royal Astronomical Society
M.A.A.A.S. = Memoirs of the American Academy of Arts and Sciences
P.A. = Popular Astronomy
P.A.S.P. = Publications of the Astronomical Society of the Pacific
P.N.A.S. = Proceedings of the National Academy of Sciences
S.F. Argonaut = San Francisco Argonaut
S.F. Bulletin = San Francisco Bulletin
S.M. = Scientific Monthly

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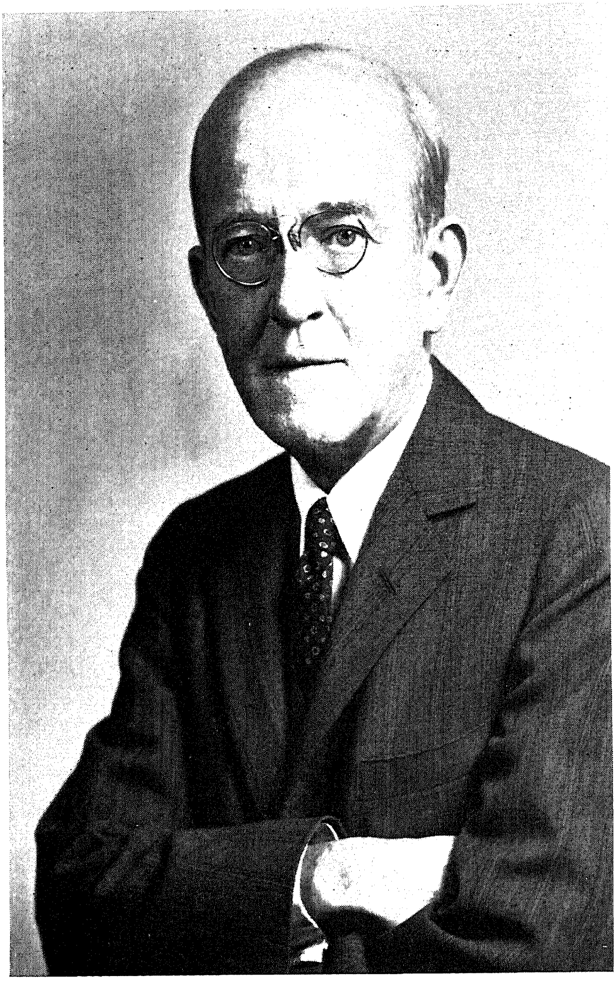

Oswald T. Avery

OSWALD THEODORE AVERY

October 21, 1877—February 20, 1955

BY A. R. DOCHEZ

OSWALD THEODORE AVERY was born in Halifax, Nova Scotia, on October 21, 1877. He came to the United States with his family at an early age, settling in New York City, where he spent all of his active scientific life. He was a man of great simplicity and singleness of purpose, endowed with unusual powers of concentration on those matters of science which aroused his curiosity; and the interest they evoked endured throughout his life. He was by nature somewhat reticent and seldom permitted the ordinary distractions of life to divert him from those scientific problems in which he was so completely immersed. The long list of his achievements which grew in importance to the very end of his life is testimony of his capacity for logical and progressive thinking and for using and developing for his purposes his own techniques and those of other sciences, particularly those of biochemistry.

Avery was graduated with an A. B. degree from Colgate University in 1900, and received his M. D. degree from the College of Physicians and Surgeons of Columbia University in 1904. After graduation from medical school, Avery spent a few years in the practice of clinical medicine, which supplied him with some amusing stories but did not attract him sufficiently for him to make his career in that field. He subsequently joined and cooperated with Benjamin White, Director of the Hoagland Laboratory in Brooklyn, where he became Associate Director of the Division of Bacteriology. Thus he instinctively selected the subject to which he was to devote his life work and in which he was later to become famous. While here he began to familiarize himself with the activities of certain species of bacteria and their relationship to infectious diseases. The work from the very beginning led him in the direction of analytical thinking and of the investigation of the subject of immunity. The character of his work attracted the interest of Dr. Rufus Cole, Director of the Hospital of the Rockefeller Institute, who invited him to become a member of that organization, with which he became associated in 1913. Here he found satisfaction and happiness and the environment which he needed for the full development of his growing interest in bacteriology. He continued as a member of the staff of the Rockefeller Hospital until his retirement in 1948 and, during this time, among other bacteriological and immunological subjects, he devoted himself in large part to the study of a single microorganism, the pneumococcus, the cause of lobar pneumonia, until more was known about that organism than about almost any other bacterium. The volume of Avery's work was large and its breadth was such that its implications for bacteriology in general and related fields were of profound significance.

During the time when Avery was progressively developing his knowledge of the pneumococcus, he promoted and engaged in, with the assistance of his colleagues, a number of important investigations of general bacteriological interest, using the pneumococcus and certain other microorganisms for this purpose. With K. G. Dernby he determined the optimum and limiting hydrogen ion concentration for the growth of the pneumococcus and showed that the observed concentrations for the growth of bacterial races are probably as definite and characteristic as those for enzyme action. With G. E. Cullen he showed that the final hydrogen ion concentration reached in the growth of a hemolytic streptococcus differed between strains of human and bovine origin as to the ultimate end point. This demonstration constituted a simple and rapid method for the differentiation of human and bovine types of streptococcus hemolyticus. It is of some interest that in the studies of the different types of pneumococcus all the fermentable carbohydrates used gave identical results in the rate of reaction change and in the final hydrogen ion concentration reached.

Avery participated with Theodor Thjotta and H. J. Morgan in a number of studies on bacterial nutrition. It had been shown that the microorganism hemophilus influenzae, a strictly hemoglobinophilic organism, will grow in hemoglobin free medium consisting of plain broth enriched by sterile suspensions or extracts of mucoid bacteria. This observation was extended by a study of the growth requirements of the so-called hemophilic bacilli of which H. influenzae served as a type. The growth stimulating action of extracts of yeast and of vegetable cells, and the importance of blood as a source of growth accessory substances were studied. The growth of H. influenzae depends upon two distinct and separable substances. Both are present in blood, but neither alone suffices for growth. One is a vitamin-like substance extractable from red blood cells, yeast, and vegetable cells, and is relatively heat labile; and the other is an iron-containing substance which is heat stable and is present in red blood cells. Both occur in plant as well as in animal tissue, so that sterile raw potato serves as a substitude for blood in the cultivation of H. influenza. Further studies showed that plant tissue also has a growth accelerating action on other microorganisms such as pneumococcus, streptococcus hemolyticus, and streptococcus viridans. It also facilitates the growth of anaerobic bacteria under aerobic conditions, since it furnishes certain necessary growth accessory substances and provides an oxidizing-reducing system whose action destroys toxic peroxides of bacterial origin.

In a series of studies in cooperation with J. M. Neill, Avery presented the results of an examination of the nature of the oxidation-reduction systems of sterile extracts of pneumococcus. These active systems consist of two components: (1) a thermo-labile constituent of the pneumococcus cell which is not removed by washing; (2) thermo-stable substances which are lacking in washed cells and which are not necessarily of pneumococcus origin, since they may be supplied by muscle infusion and yeast extract. The character of these reactions is determined by the presence or absence of molecular oxygen. In the presence of molecular oxygen, active extracts were shown to exhibit the following activities: consumption of molecular oxygen, formation of peroxide, oxidation of hemoglobin, and oxidation and destruction of the hemolysin and intracellular enzymes contained in pneumococcus extracts. All of these oxidations are examples of "oxygen activation," whereby substances themselves not reactive with molecular oxygen are easily oxidized by agents formed during the oxidation of other substances. Analysis of these processes shows that the active systems consist of two components, one of which is thermo-labile, the other thermo-stable. By themselves the thermo-stable substances react slowly with molecular oxygen to form oxidizing agents, and in the absence of molecular oxygen they establish conditions under which methemoglobin and other substances are slowly reduced. In the presence of the thermo-labile component, the reactions of oxidation and reduction are markedly accelerated. This latter component is wholly nonreactive with molecular oxygen, possesses no reducing power, and seems to be catalytic in nature. When present together, these substances constitute systems responsible for many of the biological oxidations and reductions of the living cell.

Avery in collaboration with G. E. Cullen made an interesting study of the intracellular enzymes of pneumococcus and, as a result, suggested their relationship to the metabolic activity of the cell. The demonstration of the intracellular agents was affected by breaking down the cell structure by suitable means and making extracts which were tested for enzymatic activity. In this way, active cell-free agents were obtained which hydrolyzed intact protein to some extent and which hydrolyzed peptones with striking avidity. An active esterase was also isolated as were such carbohydrate-splitting enzymes as invertase, amylase, and inulinase. On the other hand, fermentation of dextrose could not be demonstrated. These studies indicated that the enzymes described were not secretory products of the pneumococcus but were of the nature of endo-enzymes, since their activity could be demonstrated only when cell disintegration had occurred.

At the time when Avery joined the staff of the Hospital of the Rockefeller Institute, the study of the pneumococcus and its relationship to lobar pneumonia had been in progress for about three years. As a result of this study, pneumococci had been separated by means of immunological reactions into two different groups by Dochez and Gillespie. The first group consisted of Types I, II, and III, which could be sharply differentiated from one another by serological tests and were found only in association with severe examples of lobar pneumonia or in the mouths of individuals in close contact with such cases of pneumonia. The other group consisted of strains associated with lobar pneumonia in a much smaller percentage of instances, and was of greater serological diversity. These latter strains resembled the varying types of pneumococcus found in the mouths of healthy normal individuals. On his arrival, Avery joined in the study of the immunological classification of pneumococci and added to this classification several new serological types. As the study passed to other hands, many new immunological types were discovered. On the whole, the original Types I, II, and III remained fairly constant in from 60 to 80 percent of cases as the causative agents of the severe and highly fatal instances of lobar pneumonia. The results of these studies brought about a more exact knowledge of the character of pneumococcus infection of the lung, and shed a considerable amount of new light on the etiology and epidemiology of lobar pneumonia.

In 1917 Dochez and Avery reported the elaboration of a specific soluble substance by the pneumococcus during its growth in culture medium. This substance was identical immunologically with the type of pneumococcus growing in the culture and was present in large amounts at a time when little or no cell disintegration had taken place. The substance consequently did not represent dead dissolved bacterial protein, but was due to the elaboration and passage into solution of a substance which was the product of the life activity of the pneumococcus cell. That it was not an intracellular substance liberated at the death and disintegration of the pneumococcus was proven by the fact that it was already present in considerable quantities at a time when no intracellular hemolysin was present in the culture medium. The intracellular hemolysin is liberated only on the death and disintegration of the cell, and the curve of hemolysin did not begin to rise until a time when the curve of the soluble substance had almost attained its maximum elevation.

The formation of a soluble substance by the pneumococcus on growth in vitro suggested the probability that an analogous substance would be formed on growth of the organism in the animal body, and because of the readiness with which the substance passed into solution it was expected that there would be no difficulty in demonstrating it in the body fluids of animals experimentally infected with pneumococcus and in those of human beings suffering from lobar pneumonia. This was found to be the case, since a specific precipitin reaction with antipneumococcus serum corresponding to the type of organism with which the animal or human being was infected was easily demonstrated in the blood serum and urine during the period of infection. The discovery of this substance was of great importance to Avery's subsequent study of the pneumococcus, since it served as the point of departure for much of his succeeding research.

From 1922 onward, Avery, Heidelberger, and their associates undertook a chemical study of the soluble specific substances, which Avery believed were an important key to the whole subject of the immunological specificity of bacteria. Papers were published showing that the soluble specific substances of the pneumococcus were polysaccharides, the first instance in which carbohydrates were shown to be involved in immune reactions. The soluble substances of Type II and Type III pneumococci were found to be nitrogen-free carbohydrates, the former made up mainly of glucose, and the latter composed of aldobionic acid units. The Type I polysaccharide was nitrogen-containing, and made up in part of galactouronic acid.

Differences in bacterial specificity were related by Avery and

Heidelberger to characteristic chemical differences in the substances responsible; where these substances were similar, cross-reactivities were found to occur, and accounted chemically for the observed specificities. A whole new field of bacteriology, immunology, and chemistry was opened up. Many puzzling and confused observations in bacteriology and immunology were thus clarified and systematized on a rational chemical basis. At least a part of the virulence, specificity, and behavior of many important bacteria is referable to a specific polysaccharide and in the encapsulated microorganism this is the major factor. Here, then, is one of the principal foundation stones of the science of immunochemistry, which is rapidly including an ever-widening study of artificial and natural antigens.

Meanwhile, in the hands of Avery and his co-workers, knowledge of the specific characters of the pneumococci and the manner in which these are acquired had been moving to a new pinnacle of achievement. The culmination of this knowledge and of the studies conducted by Avery and his co-workers, Dawson, Alloway, MacLeod, McCarty, Taylor, and Hotchkiss, came with the announcement, in 1944, that the fundamental constituent of the transforming agent of pneumococcus Type III is a polymerized desoxyribonucleic acid. That the transformation of one type of pneumococcus into a pneumococcus of another type could occur in vivo was first demonstrated by Griffith in 1928. Studies on the mechanism of experimental transformation of pneumococcal types were carried out in Avery's laboratory from 1928 to 1948.

The transforming substance was extracted from heat-killed pneumococci or from living cells caused to undergo lysis. Sodium citrate, which inhibits the inactivating effect of pneumococcal desoxyribonuclease, was used in the lysing process in the later procedures. After deproteinization, the desoxyribonucleic acid was further purified, so that an exceedingly minute quantity, 0.0015 microgram per milliliter, was capable in vitro of inducing transformation of susceptible cells under proper cultural conditions. Evidence that the transforming agent is a nucleic acid of the desoxyribose type was obtained by chemical, enzymatic, serologic, and physico-chemical studies of highly purified material. Elementary analysis showed that the material closely resembles authentic preparations of desoxyribonucleic acid of animal origin. Serological procedures with anti-pneumococcal sera of appropriate type failed to reveal the presence of capsular or somatic polysaccharides or of pneumococcus protein in the transforming material, each of which would easily have been demonstrated by such tests.

Amino acids were obtained on hydrolysis in so small an amount that not more than 0.2 percent of protein could be present. Later studies showed that glycine from the degradation of adenine was apparently the only amino acid present in the hydrolysate, so that the possibility that a specific protein or nucleoprotein, rather than the nucleic acid itself, was responsible for the transforming activity seemed to have been excluded decisively.

Highly purified preparations of the transforming agent obtained from pneumococcus Type III made possible for the first time the induction of a predictable and permanent alteration in a heritable character of the living cell by means of a chemically defined substance of known nature. In other words, a specific mutation was induced as a result of specific treatment, an achievement which had long eluded biologists. The broad implications of the discovery of the nature of the transforming agent became apparent when it was demonstrated in Avery's laboratory that desoxyribonucleic acids, separated from a number of other types of pneumococci, possess predictable transforming activity relative to a specific cell character. Confirmatory evidence supporting Avery's interpretation of the transformation phenomenon was later obtained in other laboratories with both pneumococcus and other microorganisms.

As a result of these studies of Avery and his associates, it became apparent that certain polymerized desoxyribonucleic acids are concerned with the heredity of microbial cells in much the same fashion that genes are concerned with the hereditary characteristics of higher organisms.

The impact of these findings upon prevailing concepts of investigators in cytology, genetics, and virology, already aware that desoxyribonucleic acid is a prominent constituent of nuclei, chromosomes, and viruses, was of great importance. It was now learned that this constituent is the one functionally operative in transmitting the manifold biologic capacities and potentialities of the germ plasm. This, in turn, indicated to biochemists that nucleic acids are capable of innumerable variations in composition and structure. Both of these concepts have received considerable support, and it has become increasingly evident that they play an important part in the orienting of investigations in the several fields concerned with cellular development and differentiation.

At the time the above investigation was being presented, from its beginning to its successful conclusion in 1948, Avery and certain of his associates engaged in a number of collateral studies related to the immunological significance of carbohydrates, both those of bacterial origin and certain more common sugars. As a result of these studies an antigenic relationship was shown to exist between the polysaccharides and pneumococcus and those of certain types of Bacillus Friedlander and of a number of plant gums, such as gum acacia. Following this, a study of the specificity of certain azo-protein antigens containing simple saccharides of known chemical constitution was undertaken with W. F. Goebel. This study showed unequivocally that the specificity of carbohydrates was determined by their chemical constitution and that differences in structure, no matter how slight, were invariably reflected in the specificity of the antibodies which such antigens evoked. As an example, the specific polysaccharide of Pneumococcus Type T is characterized by the presence of a highly labile acetyl group. Gentle removal of this group deprives this polysaccharide of its antigenicity in certain animals and alters its over-all serological specificity as well.

A species-specific carbohydrate distinct from the capsular polysaccharide was isolated from the somatic component of pneumococci. This substance was designated as Fraction C. It subsequently became of considerable interest, since it gave rise to a precipitating antibody in the serum of patients suffering from pneumonia, which was present only during the acute phase of the disease and disappeared during convalescence. The antibody is not specific for pneumonia, but also occurs during the acute phase of a number of infections, such as rheumatic fever, and in conditions associated with tissue degeneration. Its presence or absence is now regularly used as a measure of the activity of the clinical condition under study.

During this time Avery in collaboration with René Dubos investigated the action of a bacterial enzyme which decomposed the polysaccharide of Pneumococcus Type III, both in vitro and in vivo. This enzyme, when injected in conjunction with virulent Type III pneumococcus, was capable of protecting mice, rabbits, and monkeys against experimental infection because of its capacity of stripping the virulent cell of its protective capsular coat. This constituted one of the very early demonstrations of antibiotic action against pathogenic microorganisms, a procedure which has since become of great importance in the cure of numerous infectious diseases.

Avery also participated with Dochez and Lancefield in an immunological classification and antigenic analysis of the hemolytic streptococcus. This study proved that this organism is not a unit type, as was previously supposed, but consists of a number of types which can be definitely identified serologically. Subsequent development and employment of the techniques used resulted in the establishment of the hemolytic streptococcus as the causative agent of scarlet fever, acute rheumatic fever, and hemorrhagic nephritis, all of which diseases may now be brought within the range of prevention or cure by antibiotic agents effective against the hemolytic streptococcus.

Avery, by his studies of the chemical basis for the differences between the several types of pneumococcus and the importance of carbohydrates in determining the antigenic specificity of bacterial and synthetic antigens, became one of the founders of the modern science of immunochemistry, a science which has rapidly come to include an ever-widening range of studies of artificial and natural antigens.

During both the First and the Second World Wars, Avery placed his scientific knowledge and skill at the disposal of the United States Government, serving on various committees concerned with the control of a number of important infectious diseases which are prevalent among troops under conditions of warfare. During his active career he received a number of honorary degrees: Sc.D., Colgate University, 1921; L.L.D., McGill University, 1935: Sc.D., New York University, 1947; and Sc.D., Rutgers University 1953. In addition, he was awarded a number of other honors and prizes, among them the Paul Ehrlich Gold Medal and the Copley Medal of the Royal Society of London. He was elected to the National Academy of Sciences in 1933 and was also a foreign member of the Royal Society of London.

Dr. Avery was a true scientist with an insatiable curiosity and a powerful and unremitting urge to discover the innermost mechanisms of the biological facts that came under his observation. His approach to the solution of a problem was characterized by a logical simplicity of thought and a perfection of technical procedure, combined with a complete objectivity that guaranteed the soundness of his deductions. Most of Avery's associations were with his colleagues, by whom he was greatly revered and who have preserved for him a timeless affection. He was a truly lovable person, humble, disinterested, and generous. The inspiring and friendly quality of his leadership is conspicuously represented by his many former associates who now occupy distinguished positions in medicine in the United States and elsewhere, so that his light still burns in many places of learning and research.

KEY TO ABBREVIATIONS

Ann. Int. Med. = Annals of Internal Medicine
Arch. Int. Med. = Archives of Internal Medicine
Arch. Pediat. = Archives of Pediatrics
Centr. Bakt. = Zentralblat für Bakteriologie
J.A.M.A. = Journal of the American Medical Association
J. Exp. Med. = Journal of Experimental Medicine
J. Infect. Dis. = Journal of Infectious Diseases
J. Med. Res. = Journal of Medical Research
Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine
Trans. Assn. Am. Phys. = Transactions of the Association of American Physicians

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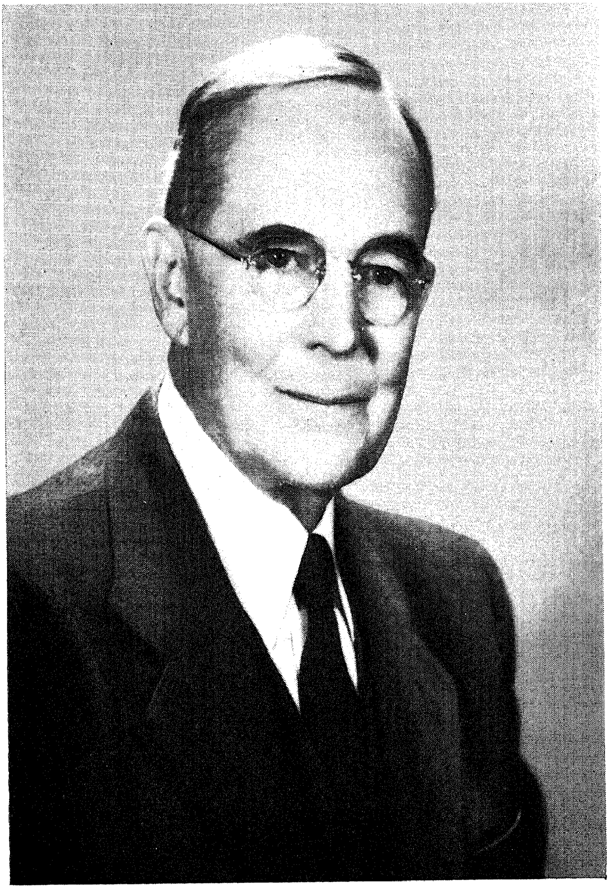
ERNEST BROWN BABCOCK

July 10, 1877—December 8, 1954

BY G. LEDYARD STEBBINS

As a scholar who saw clearly the valuable contributions which his chosen field could make to other branches of knowledge, both theoretical and applied, Ernest Brown Babcock played a significant role in the development of the science of genetics. He became a pioneer in exploring some of these extensions of genetics. Many of the foremost geneticists and plant breeders of our times received their early training through a study of the book, *Genetics in Relation to Agriculture,* which he wrote in collaboration with his colleague, R. E. Clausen. His monumental monograph of the genus *Crepis* remains to this date the foremost attempt to explain the evolution of a genus of plants primarily on a genetic basis, while considering at the time all other possible avenues of approach.

Babcock was born at Edgerton, Wisconsin, on July 10, 1877, the son of Emilius Welcome and Mary Eliza (Brown) Babcock. He received his early education in Wisconsin, and it was there that he acquired the fondness for and curiosity about the beauties of the plant world which spurred him on to his career. When he was in his teens, his parents spent a winter in California, leaving young Ernest in charge of his mother's conservatory. Here he became curious about plant forms, and, as a result, started a home flower garden. The sweet peas in this garden attracted his interest and, by scanning seedsmen's catalogues, he acquired many unusual new varieties which had just been created. Since he did more than admire these novelties, but began to wonder how and why they came to differ from each



E. B. Babcock.

other, his interest in his chosen field of science was born at that time.

During his first year of higher education at Lawrence College in Appleton, Babcock took many botanizing trips along the Fox River, and there became interested in wild plants, the second of the two interests which he was later to unite so successfully into a concerted attack on the mysteries of plant evolution. The following year, however, he moved with his family to California, where he attended normal school for two years and taught grammar scool for three more. During this time, his only contact with his chosen field of plant science was during the summer of 1900, when he served as cook and packer on a three months' camping trip in the high Sierra Nevada with two other college students, Harvey M. Hall and Harley P. Chandler. This trip began a lifelong friendship for the three men, all of whom became plant scientists on the staff of the University of California. The enthusiasm of Hall and Chandler for studying the native flora made a deep impression on Babcock, and did much to direct his later interest in genetics toward a study of wild plants and their evolution.

Finally, in 1901, Babcock's earnings as a teacher had made financially possible his entrance into the career which he desired, that of a plant breeder. Before entering the College of Agriculture of the University of California, he went to Luther Burbank to ask his advice about the value of a university course for a prospective plant breeder. This genial sage did not deny the possible value of such training, but emphasized to Babcock the importance of becoming well acquainted with plants which he was going to breed. Babcock never forgot this admonition.

Having entered the University, he found that no instruction in plant breeding was offered there. He therefore took the prescribed curriculum in agriculture, adding to it as many courses of botany as possible. In the summer of 1903 Hugo De Vries, one of the rediscoverers of Mendel's laws and the author of the mutation theory of evolution, visited the University of California. His lectures, though difficult to understand, stimulated Babcock's interest in the study of evolution.

Upon graduating from college, Babcock devoted his attention for eight years to the teaching of agriculture and to experiment station work, only part of which was in plant breeding. In 1907 he began his first project in plant breeding, at the newly formed Citrus Experiment Station in southern California. The raising of peaches in that section of the country was hazardous, because in most years the winter chilling is not enough to bring about the right conditions of dormancy in commercial peach varieties, and thus to enable them to respond to spring temperatures by uniform flowering and leafing. Babcock noticed that a Chinese peach variety with very inferior fruit was an exception to this rule, and performed consistently well under southern California conditions. He therefore set about combining this desirable growth rhythm with good fruit quality by crossing this Chinese variety with the well-known commercial variety Elberta. Babcock left his position at Riverside before the experiment was finished, but his successors selected from the progeny of his cross a variety with good quality and consistent performance in southern California, which they named after him.

In 1908, Babcock married Georgia Bowen, a childhood friend and neighbor from Edgerton, Wisconsin. In the same year, he joined the faculty of the University of California at Berkeley, where he remained until his retirement in 1947. In his new position, he began an investigation of a curious form of the California black walnut, whose leaves bore a superficial resemblance to those of the California live oak, and eventually demonstrated that it was a spontaneous mutation.

In 1913, Thomas Forsyth Hunt became Dean of the College of Agriculture, and undertook a complete reorganization of its curriculum. He asked Babcock to take charge of one of four basic courses of the new curriculum, namely, the principles of plant and animal breeding. As a result, Babcock organized the Division of Genetics, one of the first departments of its kind in the country. He was made

Professor of Genetics and head of the division, a position which he held for thirty-four years until his retirement in 1947.

Babcock had thus achieved his early expressed desire to become a plant breeder. Furthermore, he entered into the new science of genetics in the middle of the golden age of its development, when the spectacular discoveries of T. H. Morgan and his coworkers were convincing the biological world of the general validity and immense importance of the chromosomal theory of heredity. Babcock first devoted his attention to the difficult problem of teaching these new discoveries in terms of their significance to practical problems of plant and animal breeding. In 1914, he added to his department a brilliant young instructor R. E. Clausen, who was associated with him throughout the rest of his life, and who succeeded him as head of the Department of Genetics. Together, they produced a textbook, *Genetics in Relation to Agriculture,* the first in its field. As soon as it appeared in 1918, this text became immediately popular, and during the 1920s and '30s it was one of the most widely used of genetics textbooks. A second, greatly expanded edition, appeared in 1927.

When his teaching program had become well established, Babcock began to look around for suitable material with which to begin a long term program of research in plant genetics. He believed that, although the impressive conclusions reached by the *Drosophila* workers were almost certainly applicable in their essential features to all animals and plants, corroborative evidence should be obtained from other organisms before they could be considered as firmly established. Since the success of the *Drosophila* research depended partly upon the fact that this fly has a low chromosome number, Babcock's attention was attracted by a plant genus which also had been found to contain species with only six chromosomes. This was *Crepis,* a small weedy relative of the dandelion. In addition, he found that the species of *Crepis* are easy to raise in the greenhouse, have a short life cycle, and can be hybridized without great difficulty. Moreover, the genus contains a large number of species with very diverse characteristics. Consequently, he reasoned that in *Crepis* the geneticist could study not only the properties of a single genetic system, but in addition the relationships between different systems. This, he concluded, would provide fundamental evidence concerning the nature of the processes of evolution.

In 1918, he formed a research team of three workers: J. L. Collins, who did most of the breeding work, Margaret C. Mann (later Mrs. J. W. Lesley), who carried out the first cytological studies, and himself as taxonomist and general planner. This group brought together a number of species, began interspecific hybridization, and studied certain individual genetic characteristics particularly in *C. capillaris*. After a few years, they realized that for various reasons *Crepis* could not be used for chromosome mapping studies like those of the Morgan school in *Drosophila,* but that it was, nevertheless, favorable material for studying interspecific relationships from the cytological and genetic point of view. After 1925, therefore, the research on *Crepis* was directed almost entirely toward obtaining evidence from cytology and genetics to supplement that from external morphology regarding the interrelationships of species. His original associates, Collins and Mann, were followed by a series of coworkers and students, some of whom were well known before their sojourn at Berkeley, and others later became eminent cytogeneticists in their own right. Among them were Lillian Hollingshead, Jens Clausen, M. S. Navashin, A. Müntzing, D. R. Cameron, J. A. Jenkins, S. L. Emsweller, and M. S. Walters. The investigations carried on in collaboration with these workers established a series of basic facts about the evolution of species in the genus. Species differentiation was found to involve three different kinds of genetic changes: gene mutations; structural changes of the chromosomes, which sometimes caused alterations in the basic chromosome number; and polyploidy. The latter phenomenon was found only in a few groups. Furthermore, certain definite phylogenetic trends were discovered in the somatic chromosomes, particularly reduction in size and basic number in association with the evolution of the annual habit of growth. These findings were reported in a number of publications, particularly a partial monographic study of *Crepis* by Babcock and Navashin in *Bibliographica Genetica* for 1930, and were summarized in a display of the phylogeny of *Crepis,* illustrated by living plants, and presented at the Sixth International Congress of Genetics at Ithaca in 1932. In 1930, Babcock made an extensive tour of the Mediterranean region, becoming familiar with many species of *Crepis* under natural conditions, and augmenting greatly his collection of living material.

After he had studied living material of more than half of the species, he realized that he could not understand fully the evolution of this genus unless he also learned something about the genera related to it. In 1935, therefore, aided by grants from the Carnegie Institution of Washington and the Rockefeller Foundation, he began a collaboration with G. L. Stebbins and J. A. Jenkins with this in mind. A cytological survey of these related genera was followed by a monographic study of one of them, *Youngia,* and a series of shorter studies on others. As a result, the limits of the genus *Crepis* became sharply defined, and its position in the tribe Cichorieae of the family Compositae was accurately determined. A byproduct of this collaboration was an intensive study of the North American species of *Crepis,* which was presented as a model for the systematic treatment of plant genera characterized by the presence of both polyploidy and asexual or apomictical reproduction.

During the last few years before his retirement, Babcock worked intensively on the final stages of his *Crepis* monograph. He arranged the species into sections, and worked out a phylogenetic scheme for the relationships between them; he compiled the data on chromosome numbers and morphology, crossability, and chromosome behavior in the hybrids, and geographic distribution; and he made a careful and comprehensive study of the historical geology, paleontology, and plant geography of Eurasia. As a result of this study, and of his ability to synthesize and to see the relationships between the facts which he had assembled, he was able to put together a coherent and logical account of the origin, evolution, and migration of the 196 species of *Crepis* which he recognized. This was the first attempt of a botanist to explain the evolution of such a large number of species on the basis of such a large body and wide range of types of evidence; and Babcock's *Crepis* monograph still remains unique in this respect.

Published in 1947, his year of retirement, by the University of California Press, the monograph was recognized at once by botanists as a milestone in the progress of plant systematics and evolution. Its breadth of scope attracted the attention of many botanists working in these fields, while its accuracy, clarity, and careful attention to detail brought forth the commendations of specialists on the various floras in which *Crepis* is native. It was the crowning achievement of one of the most eminent students of plant evolution of his generation.

Babcock's work did not end with his retirement. He first occupied himself with compiling a brief history of the science of genetics, much of which he had followed during his lifetime. This was accompanied by a study with his last graduate student, M. B. Hughes, on self incompatibility in *Crepis foetida,* as a result of which a new type of genetic determination for self sterility was established.

Finally, he turned his attention to the application of genetics toward replenishing our decreasing resources of forest products. Since 1932, he had been an adviser of the Institute of Forest Genetics at Placerville, California, and had taken an active interest in its work. During much of this time the Institute had been an "orphan" of the Forest Service, receiving totally inadequate support, and continuing to make valuable contributions only because of the dedicated service of a few research workers. In 1950, Babcock, along with Dr. F. I. Righter, Director of the Institute, aroused the interest of S. N. Wyckoff, a former director of the California Forest and Range Experiment Station. Together they formed the Forest Genetics Research Foundation, and assembled a board of sponsors which included most of the eminent geneticists of the nation. This approach bore the expected results, and by the first part of 1954 the Institute of Forest Genetics had received from Congress a greatly increased appropriation. His final paper, "Future Forests and Heredity," which appeared in the journal *American Forests,* did much to stimulate the now active interest in the application of genetic science to tree breeding. The fact that his final work was directed toward helping some of his fellow geneticists to overcome their difficulties, and toward helping to increase natural resources which will be required by future generations, illustrates at the same time the affection for his fellow men and the far-sighted altruism which were the outstanding personal characteristics of Ernest Babcock.

He was elected to the National Academy of Sciences in 1946, and held office in numerous professional societies. He was President of the Western Society of Naturalists in 1929, of the California Botanical Society in 1940, of the Society for the Study of Evolution in 1952, and of the California Academy of Sciences in 1954. He was Vice President of the American Society of Naturalists in 1934, and Associate Secretary Pacific Division, A.A.A.S., in 1952. The University of California honored him with its Faculty Research Lectureship in 1944, and with the degree of LL.D. in 1950.

To those who knew him casually or intimately, Ernest Babcock was much more than an eminent scientist. He was one of those rare personalities whose kindliness and affection for his fellow men dominated his whole nature. He was particularly interested in students or fellow scientists who needed assistance of any kind. Through his help, a large number of students, particularly from foreign countries, were able to complete their higher education, and several older and well-known scientists obtained better opportunities for work or more congenial surroundings for their years of retirement. Ernest Babcock's abiding faith in the goodness of mankind and his cheerful outlook toward life gained him the friendship and affection of a large circle of his fellow men.

KEY TO ABBREVIATIONS

Amer. Nat. = American Naturalist
Calif. Agr. Expt. Sta. Cir. = California Agricultural Experiment Station Circular
Carnegie Inst. Wash. Yearbook = Carnegie Institution of Washington Yearbook
Jour. Bot. = Journal of Botany (British)
Jour. Hered. = Journal of Heredity
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences
Univ. Calif. Jour. Agr. = University of California Journal of Agriculture
Univ. Calif. Publ. Agr. Sci. = University of California Publications in Agricultural Science
Univ. Calif. Publ. Bot. = University of California Publications in Botany

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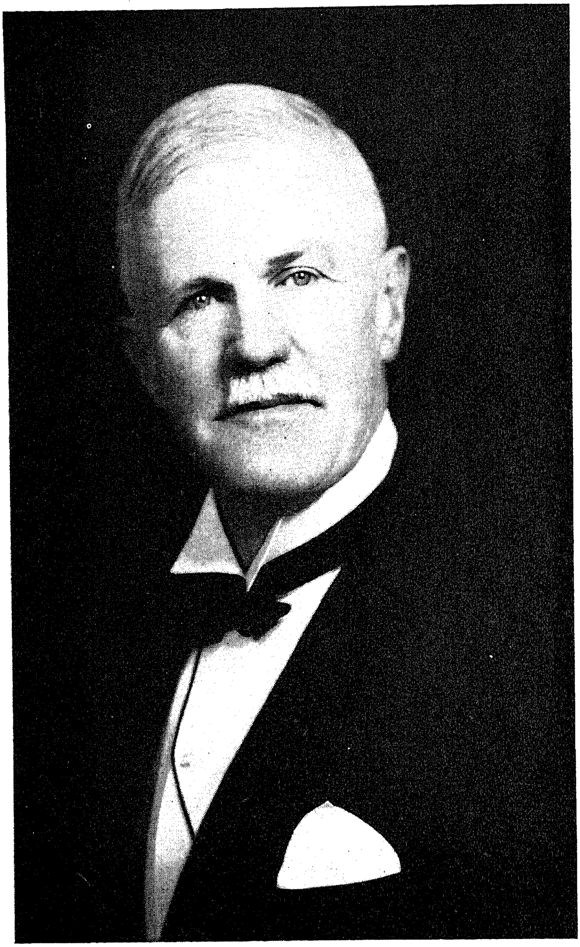

Francis G. Benedict

FRANCIS GANO BENEDICT

October 3, 1870—May 14, 1957

BY EUGENE F. DuBOIS AND OSCAR RIDDLE

FRANCIS GANO BENEDICT was trained as a chemist at Harvard and Heidelberg. At Wesleyan University he shared in important biochemical studies, and while there developed a capital mechanical device. As director (1907–1937) of Carnegie Institution of Washington's Nutrition Laboratory, in Boston, he became one of America's leading physiologists and perhaps the foremost investigator of gaseous metabolism of his time.

He was born October 3, 1870, in Milwaukee, Wisconsin, the son of Washington Gano and Harriet Emily (Barrett) Benedict. A paternal ancestor was Thomas Benedict, who came from England about 1645 and settled near Providence and Pawtucket, Rhode Island. Frank was named for another paternal ancestor, François Gano, who, during a religious war, escaped from his native France in a whiskey barrel. When Frank was seven years old, the family moved to Orange Park, Florida, and in his eleventh year they moved to Boston. He belonged to a musically inclined family that added piano lessons to his public school education in these various cities.

When about thirteen years old he attended a lecture in Boston by Professor James F. Babcock on "A Basket of Coal," which opened his eyes to the wonders of chemistry. Thereafter he set up a laboratory in the cellar of his home where, without supervision, he performed experiments and fortunately avoided blowing himself to pieces. One suspects that the outfitting and prolonged maintenance of this self-made laboratory must have developed some of the mechanical skills, and familiarity with numerous gadgets which were later of much use to the builder of ingenious devices for measuring the heat production of man, mouse, and elephant.

For one year following his graduation from public high school in Boston, Frank studied chemistry exclusively, at the Massachusetts College of Pharmacy and later, while an advanced student at Harvard (1892–1894), he also served as instructor in chemistry at that college. He entered Harvard at the age of nineteen. There, he had the most important experience of his life in his association (as pupil and assistant) with Josiah Parsons Cooke, the professor of chemistry. He was granted the A.B. degree in 1893, remained for a year of graduate study, and obtained the A.M. in 1894. These five years at Harvard were years of exceptionally hard work which excluded all extracurricular activities. Indeed, the usual games and sports remained always foreign to the boy and man. His father, a business man, disapproved of collegiate training for the son, wished for him a career in business and music, and frowned upon sports because they might disable the hands for piano playing. At the end of an additional year of graduate study, chiefly under Victor Meyer, Heidelburg University granted him a Ph.D., *magna cum laude,* in 1895.

As research assistant to Professor W. O. Atwater, he began an association with the chemistry department of Wesleyan University, Middletown, Connecticut, in the autumn of 1895. Here Dr. Benedict advanced from instructor to professor (1905–1907). From 1895 to 1907 he also held an appointment as physiological chemist in the U. S. Department of Agriculture, and from 1896 to 1900 as chemist at Storrs Experiment Station. In these several posts at Middletown his research was closely associated with that of the distinguished physiological chemist, Dr. Atwater, and the transformation of chemist to physiologist got well under way. In these early years Dr. Benedict made what he regarded in 1924 as his first important contribution to science. In his own words:

"The development of the closed circuit respiration apparatus and calorimeter at Wesleyan University is, in my judgment, the most important mechanical contribution I have been privileged to make. This was developed from the ground up, based upon the idea that if the actual amount of oxygen absorbed by the human body in life processes could be directly measured such a measure would have great significance in the comparison with the simultaneous heat production."

Similarly one could note that, also in 1924, he regarded his study of the chemical composition of the atmosphere, particularly its oxygen content (1912), as the most important *chemical* study he had ever made.

Early in the Wesleyan period, in 1897, Frank was married to Cornelia Golay, of Brewer, Maine. Their maternal grandfathers were brothers, and both were physicians. Mrs. Benedict was a Vassar graduate trained in zoology and biology. Somewhat later, at the Nutrition Laboratory where physiological studies predominated, she shared fully in the conduct and publication of several valuable studies. That the Middletown researches with the calorimeter were of much significance in medicine was early recognized by at least three medical leaders of the day—Doctors Welch, Billings, and Keen. Largely through their initiative the Trustees of Carnegie Institution of Washington were led to establish the Nutrition Laboratory in Boston, and Dr. Benedict was appointed as its director (1907–1937). Built alongside Harvard's Medical School, this soon became famous as one of the leading research laboratories of America.

While the new laboratory was under construction, early in 1907, the Benedict family made the first of its many trips to Europe. Establishing his wife and his daughter, Elizabeth, in Geneva, Frank began an acquaintance with most of the leading physiologists of Europe, and brought back to his unfinished laboratory a fresh view of results, methods, equipment, and persons currently connected with the evolving problems and purposes of that new laboratory. All this he regarded so highly that he planned thereafter to repeat these visits at approximately three-year intervals. With the exception of the years of the First World War, this was done. On these trips abroad he lectured most liberally, often in German or French. Though he was relatively inactive in the strictly professional societies of his own country, the work of few American physiologists was so quickly and widely known in Europe as that of Benedict.

At the Nutrition Laboratory his research activities were divided, necessarily, between the devising and adequate testing of new or simplified appliances and the actual use of these instruments in studies on those vital activities which were his main objective and interest. Though little more than a casual reference to these numerous appliances and instruments can be made in these pages it should be observed that they constitute a major contribution to physiology. He built two "small" calorimeters of the Atwood-Rosa type and devised several much smaller and relatively inexpensive instruments for measuring the oxygen consumption as a means of estimating the energy production. One such device is the small "Benedict apparatus" since used widely in hospitals and doctors' offices for measuring the metabolism of patients (1916–1918). Other devices were adapted to measuring the heat production of man and of animals varying greatly in size—from the 8-gram dwarf mouse, the rat, and the pigeon to the python, the steer and the 4,000-kilogram elephant.

One of the writers of this memoir was a follower of Benedict in the field of calorimetry and metabolism.

In the Russell Sage Institute of Pathology, Bellevue Hospital, New York, we built a human calorimeter for the study of disease—following closely the design and experimental method used by Benedict in his 'small' calorimeter. We there found that the Benedict apparatus and methods of calculation were extraordinarily accurate. When I later used his smaller, simpler universal or unit apparatus and the Benedict-Collins small spirometer these also were found to be accurate and very useful. In the course of this work I had to study all of Benedict's publications in great detail, and I do not remember finding a single miscalculation, or a statement that was not supported by evidence. (E. F. D. B.)

Dr. Benedict repeatedly said that the unifying aim and objective of most of his studies was to uncover the laws governing those vital activities most closely related to heat production and heat loss in the human and animal organism. Pursuit of this aim committed him to several types of precise measurement: direct measurements of the heat given off by the body; quantity of carbon-dioxide produced; more especially, the quantity of oxygen consumed; loss in weight of the body from hour to hour; losses from each of the several paths of heat loss; the temperature of the skin and body trunk; and several of the metabolic accompaniments of muscular work, such as walking, riding a bicycle, and stair climbing. One particular and quite comprehensive program of study emerged during his first decade at the Nutrition Laboratory and this was destined to become his foremost interest during the last half of his studies there. This involved a wide survey of the comparative metabolism of animals. His initial concentration on the human being was, in a sense, a preparation and part of this broader study. He came to regard both small and large warm-blooded species as the more essential part of this program. Of the cold-blooded animals, only representatives of large species—large snakes and giant tortoises—were included, since Krogh and others had undertaken adequate studies of the smaller species.

With these aims, and through use of his several types of calorimeters during a span of forty years, Benedict and his many collaborators added much to our understanding of heat production and heat regulation in humans and animals, in infancy and old age, in races, sexes, hybrids, and several other related subjects. More especially, he examined with much skill and success the conditions requisite for a measurement and calculation of the so-called "basal" metabolism in man and a score of species of other mammals, birds and reptiles, and he greatly extended our knowledge of the comparative metabolism of vertebrate animals.

Harris and Benedict (1919) provided standards based on age, sex, height, and weight which are still most useful for comparing the metabolism of a patient with that of the normal person. With Osborne he determined the heat of combustion of several vegetable proteins. An intensive study of the respiratory metabolism in diabetes by Benedict and Joslin is one of the most important ever made of that disease. With Carpenter he provided sound information on a variety of topics that included the respiratory exchange, metabolism during rest and during fever, and the stimulating effect of nutrients. With one or another collaborator he made several studies on the physiological effects of alcohol. With R. C. Lee he studied lipogenesis in the goose, and hibernation in the woodchuck. Other collaborators were numerous, some of them working elsewhere than in Boston (Ritzman, MacLeod, DuBois, Fox, Riddle, Sherman, Steggerda, Wilson). Results from this large group of studies—even a list of the problems more or less successfully attacked—must remain unnoted here. The variety and scope of those numerous studies is indicated in the appended Bibliography. Many of those results were brought together, and subjected to scholarly analysis, in the last (1938) of Dr. Benedict's monographic publications, *Vital Energetics: A Study of Comparative Basal Metabolism.* This book is the outstanding classic in his field of study; it is one of the classics of physiology.

Of course, it cannot be assumed that all of Benedict's published views on basic questions of respiratory metabolism remained unchanged during his long career, nor that some of those views remained unchallenged by colleagues in this field of study. In earlier years Benedict considered "basal" values as more firmly fixed than was consonant with his later findings in several species of animals. In contrast to the constancy observed in humans (except in emotional disturbances, 1935) he concluded (with Ritzman, 1935) that, "In view of the lability of the basal metabolism of dairy cows, the concept of constancy in basal metabolism of animals must be revised." Less marked lability he had earlier observed (with Riddle, 1930–34) in doves and pigeons, and he was later to find (with Lee, 1937–38) surprising fluctuations in the goose and in the non-hibernating phase of the woodchuck.

As a part of comment on this topic perhaps a reference to a personal experience of each of the two writers of this memoir is not inappropriate. One of us collaborated with Benedict during a period of almost ten years.

At the beginning of this work, done with doves and pigeons in my laboratory, I found him quite reluctant to grant the possibility that the hormones (other than that of the thyroid) may be a significant factor or factors in the heat production of animals—more especially, the possibility that they are responsible for temporary and cyclical increases in heat production. Later results—obtained both in our collaboration and in the work of others—apparently made that view acceptable to him, but he developed no program for a personal study of that area. Actually his later interests centered more and more in the comparative basal metabolism of adults of various species (1938)—not that of the individual, the sex, or even the race. Interestingly enough, this restriction of main interest seems in the end to have resulted in an extension of his concept of lability and of multiple causation within both areas—that of heat production in different species, and at different periods in the adult individual. In his final monograph (1938), dealing with species difference in adult animals, he lucidly documented his confidence in a fairly wide divergence and inequality of the basal heat production of the various warm-blooded species, in the lability (occasional) of basal heat production, and in the views that heat production is far more meaningful than heat loss, and that heat production varies in response to a wide and still inadequately explored range of conditions and tissue stimuli. (O.R.)

The other author of this memoir was brought up in a school of nutrition that considered the surface area an important factor in basal metabolism, though the school never stated very clearly whether or not it considered surface area a causal factor.

Benedict, on the other hand, maintained that if the surface area were useful in estimating the normal metabolism that this was in more or less accurate relationship—but not causal. As a result of this difference in theory he and I had a long controversy in the literature.

Fortunately, it was always a friendly controversy. Indeed the hotter the arguments the stronger our friendship became, and we both enjoyed the dispute which stimulated some of our best work. Eventually Benedict and I came to almost the same viewpoint in a position almost halfway between the two extremes. The question is still the subject of dispute, and may long remain unsettled. (E.F.D.B.)

Early critical comment maintained that Benedict's lack of initial biological training led the Nutrition Laboratory to a too restricted program of studies and to occasional errors of procedure. In regard to the latter he was indeed frustrated in his study of the periodic (monthly) variation of the metabolism of women through failure to recognize that ovulation, not menstruation, was the critical time and point in such a study. His avoidance of the field of vitamin research—a large area of nutrition whose emergence practically coincided with the founding of his laboratory—disappointed many during one or two decades. In retrospect it can be seen that the unfolding of both the vitamin story and that of the gaseous metabolism warranted the establishment of separate laboratories or institutes. Perhaps the same observation applies to the circumstance that the Nutrition Laboratory remained aloof from the quite coincident and highly significant development of knowledge of cellular respiration and the enzymes involved in that process.

Benedict's disagreements with Rubner, as recorded in the literature, relate especially to the use and significance of surface area in calculations of heat production and to the role of temperature in metabolism measurements made for comparative purposes. In his private notes for the year 1913 he wrote: "It is always a matter of great regret to me that Prof. Rubner is so disinclined to discuss scientific matters. I have never been able to draw him out to any length in scientific discussion either in his visit to America or later in my visit to Berlin." Mentionable too is Benedict's unreported attempt, some twenty years later, to lessen this area of controversy through friendly and prolonged personal correspondence. This effort, however, was a deep disappointment to Benedict. When he later wrote (1938) his summarizing monograph, *Vital Energetics,* these disagreements were candidly but most courteously reexamined.

Though only the studies of a later day can properly assess some of Benedict's theoretical views, it is perhaps significant that those most familiar with his total contribution are commonly the ones most impressed by the magnitude and coherence of that contribution. Added to indispensable and often expensive instrumentation, made quickly available to colleagues, was a steady flow of the results of keen observation and accurate measurement. During forty years he was a careful planner of experiment and a meticulous guardian of method. Continuously, he was a source of science-building fact. Ultimately, a foremost designer of the outlines of whatever respiratory metabolism now seems likely to contribute to the comparative physiology of man and other air-breathing vertebrate animals.

The list of Dr. Benedict's publications includes nearly 300 titles. Thirty-three of these exceed 100 pages, and eight of them contain from 301 to 712 pages. This list does not include his 30 Annual Reports as director of the Nutrition Laboratory to the Trustees of Carnegie Institution on the accomplishments of the year in his laboratory. Though his collaborators did much of this writing, he was a prodigious writer, commonly using the rather unusual method of dictating to a secretary or dictaphone. This sometimes resulted in books or papers that were too long, but it was his way of making the results of his studies available to others. Thirty-five contributions were published in foreign journals in French or German.

Here one may reflect momentarily on one circumstance that was peculiarly—probably vitally—favorable to Benedict's highly productive career. This sustaining circumstance was his early and influential association with the Carnegie Institution of Washington. During the decades in which his work was planned and done, most of his colleagues in physiology could find only meager financial support for either their research or their more expensive publications. Though the apparatus he developed was exceptionally expensive, though the use of this equipment in actual research often required uncommonly costly assistance and materials, and though the cost of publication of a stream of monographs was beyond the resources of nearly all American universities, these restraining barriers were avoided or minimized for him. The resources and foresight of Mr. Andrew Carnegie, sustained by the vigilant interest of officers of the institution he founded, continuously smoothed the way for the personal bent and talents of this investigator.

Frank Benedict was elected a member of the National Academy of Sciences in 1914, of the American Philosophical Society (1910), of the American Academy of Arts and Sciences, and of the Society of American Magicians (1930); of the Boston Branch of this society, in the twenties. He received the medal of the National Institute of Social Sciences in 1917, "in recognition of his valuable contributions to human energetics and the alcohol problem"; and the gold honor medal of the University of Hamburg in 1929, "in recognition of his successful work in metabolism and physiology." He was an honorary member of scientific or medical societies centering in Paris, Brussels, Halle, Budapest, and Vienna. Honorary Sc.D. degrees were conferred by Wesleyan University (1910) and the University of Maine (1924). He was given an honorary M.D. by the University of Würzburg in 1932.

Benedict held quite inflexible views on some social questions. He was an enemy of alcohol, but an honest enemy. His published researches on this substance are unbiased accounts of its physiological effects. In the days when Maine was a prohibition state, he once assumed chief responsibility for stopping the illegal sale of liquor in Machiasport by apprehending the seller. The family of the latter were friends of the Benedicts, but Frank considered this neighbor a menace to the town. He was highly suspicious of the power of labor unions and strongly resented it when, on one occasion, the union tried to get him to discharge some of the nonunion workers in his laboratory. Again, during the construction of his laboratory he was bothered by some plumbing inspectors. To settle this matter, he himself took the examinations and became a licensed plumber. Thereafter he proudly showed this license not only to inspectors, but to visitors as well.

Frank Benedict was a large man, always dignified and impressive. He was full of energy, always interesting in his conversation, considerate of others, good natured, kindly, self-confident. He was also impatient with excuses, and could be sharply critical of an inadequate performance or of an individual not accommodated by his standards. He was scrupulously careful in financial matters. He had a lively sense of humor, and was unusually good as a lecturer—well understanding the art of showmanship; his talks were always well planned and clear, appropriately illustrated with lantern slides and a few anecdotes. He had a strong aversion to profanity and shady stories. Inwardly, he was religious. Magic and the piano, "played for my own amazement," were his chief hobbies. His color-blindness failed to destroy his pleasure in circuses and museums. Beyond these hobbies was his lifelong interest in international amity. This he pursued through a voluminous correspondence with his many friends in Europe and Japan— in addition to the visits, lectures, and use of European publication facilities already noted. A hard worker in the laboratory, his happiest hours seem to have been those spent in his summer home at Machiasport with its beautiful view of the coast of Maine.

On his retirement as director of the Nutrition Laboratory, November, 1937, he widely advised his colleagues that this also marked the termination of his scientific efforts and interests. During the earlier years that followed he sometimes left his Machiasport home for lecture tours—using "Magic and Science" and "The Physiology of the Elephant" as subjects. He suffered an almost fatal accident in April, 1940, when struck by a taxicab in downtown Boston. After a long convalescence, he again lectured occasionally, but usually found it better to spend the winter months in California, New York City, or Florida. Though unable to travel to California (or elsewhere) during his last years his former visits there had permitted him to be close to most of those who survived him—his widow, Cornelia Golay Benedict; his daughter, Elizabeth Harriet (now Mrs. Henri Hänggi); and his grandchildren, Dr. Cecil E. Leith and Cornelia Sarah Garbesa. He died in Machiasport on May 14, 1957.

Frank Benedict had the good fortune to use a talent and a durably strong hand in creating both basic and applied physiology in America, and to pass along that creation and related American learning quickly and persuasively to Europe. He was a citizen and untiring worker much honored at home and abroad.

KEY TO ABBREVIATIONS

Am. Chem. Journ. = American Chemical Journal
Am. Journn. Diseases Children = American Journal of Diseases of Children
Am. Journ. Obst. Gynecol. = American Journal of Obstetrics and Gynecology
Am. Journ. Phys. Anthrop. = American Journal of Physical Anthropology
Am. Journ. Physiol. = American Journal of Physiology
Ann. Physiol. = Annales de Physiologie
Arch. f. d. ges. Physiol. = Archiv für die gesamte Physiologie
Arch. Intern. Med. = Archives of Internal Medicine
Biochem. Ztschr. = Biochemische Zeitschrift
Boston Med. Surg. Journ. = Boston Medical and Surgical Journal
Bull. Soc. Scient. d'Hygiène Alimen. = Bulletin de la Société Scientifique d'Hygiène Alimentaire
Chinese Journ. Physiol. = Chinese Journal of Physiology
Deutsch. Arch. f. klin. Med. = Deutsches Archiv für klinische Medizin
Indus. Eng. Chem. = Industrial and Engineering Chemistry
Inst. Expt. Med., Leningrad = Institute of Experimental Medicine, Leningrad
Journ. Am. Chem. Soc. = Journal of the American Chemical Society
Journ. Am. Med. Assoc. = Journal of the American Medical Association
Journ. Biol. Chem. = Journal of Biological Chemistry
Journ. Mammal. = Journal of Mammalogy
Journ. Med. Research = Journal of Medical Research
Journ. Nutrition = Journal of Nutrition
Journ. de Physiol. et de Path. gén. = Journal de Physiologie et de Pathologie générale
New Eng. Journ. Med. = New England Journal of Medicine
New York Med. Journ. = New York Medical Journal
Proc. Am. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
Proc. Am. Philos. Soc. = Proceedings of the American Philosophical Society
Proc. Am. Soc. Animal Nutrition = Proceedings of the American Society for Animal Nutrition
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Schweiz. Med. Wochenschr. = Schweizer Medizinische Wochenschrift
Sci. Am. Supp. = Scientific American Supplement
Sci. Monthly = Scientific Monthly
Skand. Arch. f. Physiol. = Skandinavische Archiv für Physiologie
Storrs Agric. Expt. Sta. = Storrs Agricultural Experiment Station
U. S. Dept. Agric., Office Expt. Stations = United States Department of Agriculture, Office of Experiment Stations
Univ. New Hampshire, Agric. Expt. Sta. Tech. Bull. = University of New Hampshire, Agricultural Experiment Station Technical Bulletin

Verhandl. d. phys.-med. Gesellsch. zu Würzburg = Verhandlungen des physikalische-medizinische Gesellschaft zu Würzburg
Yale Journ. Biol. Med. = Yale Journal of Biology and Medicine

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CHARLES WHITMAN CROSS

September 1, 1854—April 20, 1949

BY ESPER S. LARSEN, JR.

CHARLES WHITMAN CROSS will be remembered for his detailed, painstaking geologic field work in Colorado, and for his contribution to the classification of igneous rocks in the quantative classification of igneous rocks by C.I.P.W. He was born at Amherst, Massachusetts, on September 1, 1854, the son of the Reverend Moses Kimball Cross and Maria (Mason) Cross. From Amherst College he received the B. S. degree in 1875.

It was the common practice in America seventy years ago for young men preparing to be scientists to attend a German—or at least a European—university. Accordingly, Cross attended Göttingen in 1877, and received his Ph. D. in Leipzig under Zirkel in 1880. He returned to the United States, joined the U. S. Geological Survey as "geologic and microscopical assistant" and for some years was stationed in the Denver office under Dr. S. F. Emmons.

In his early years in Colorado, Cross wrote chiefly papers on mineralogy with Hillebrand and Eakins. Later he presented papers on geologic subjects including the Pikes Peak folio, the Anthracite and Crested Butte folio, the geology of the Rosita Hills, the geology of the Denver Basin, general geology of the Cripple Creek District, and many other papers.

About 1895 he became interested in the San Juan Mountains of southwestern Colorado. He first studied the mining districts of Telluride, La Plata, Rico, Ouray, Silverton, Lake City, and Needle Mountains. He continued his work in southwestern Colorado for

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many years, and he and his assistants mapped in some detail an area about a hundred miles square. The study included the mapping and description of a great complex of pre-Cambrian rocks, Paleozoic, Mesozoic, and Tertiary sedimentary rocks, and a complex of Tertiary volcanic rocks. In this study he made great contributions to many geologic problems, including the stratigraphy and structure of the area and most especially to the complex volcanic history. Cross began his work in the western part of the area in which he prepared seven folios of the U. S. Geological Survey. Other papers have been published, and a monograph concerning the whole area has recently appeared.

Cross no doubt selected the San Juan Mountains because of their grandeur and beauty, with fourteen peaks over 14,000 feet in elevation in the central mountains mass, and some of the bordering valleys reaching below 6,000 feet. The region furnishes water to the three great river systems of the Southwest, the Mississippi, the Colorado, and the Rio Grande. Clear swift streams are present in all the valleys, and waterfalls are numerous. Sage brush and other desert brush occupy the lower slopes to about 8,000 feet in elevation. Scattered pine is in the upper part of the sage brush, and spruce, aspen, and some fir are above that to timber line, which is about 11,500 to 12,000 feet. At timber line the spruce is dwarfed and gnarled; above timber line are willows.

Wild flowers are present in great variety, with the alpine types at high altitudes and more familiar types on the lower slopes. Above timber line the alpine flora forms a delicate carpet of great beauty. On the lower slopes, in any place where the timber is not too dense, the profusion of flowers gives the fields and hills solid masses of color. The dainty blue Colorado columbine (Aquilegia Caerolea), state flower of Colorado, is the most attractive, though not the most common. The great fields of larkspur are common on the northwestern slopes below the timber. Paintbrush, monkshood, lupine, and many other flowers grow in the greatest profusion.

While Cross was working in the mountains there were few roads, The field work by Cross was done with horses or on foot, and camp was moved by pack train, on muleback. The country was wild and difficult to traverse, but Cross believed in living comfortably and his camp unit was one of the best in the west. He had had much experience with such camps and he knew that he must have superior camp men and a comfortable, adequate outfit. He selected camp sites with care and usually had a beautiful view and pleasant surroundings. In the mountains there are thunderstorms nearly every day during July and August. Toward the end of August there might be a snowstorm and from then on no thunderstorms, but delightful cold weather.

Cross was active in organizing the National Research Council. He was a member of the Council from 1918 to 1922, treasurer during 1918 and 1919, and vice-chairman of the Division of Geology and Geography in 1918. He was elected to the National Academy of Sciences in 1908 and was treasurer from 1911 to 1919. He was a member of the Geological Society of America and President of the Society in 1918. He was an honorary member of the Colorado Scientific Society, the Geological Society of Washington (President in 1899), the American Philosophical Society, and the Washington Academy of Sciences. He was a corresponding member of the Academy of Natural Science of Philadelphia and a member of the London Geological Society. He was Associate in Petrology, Smithsonian Institution, from 1920.

He was active in organizing the Petrologists Club and for many years in its early days it met in his study.

Cross was a petrologist and one of the leading field geologists of his generation. Most petrologists of his time were interested chiefly in the description and classification of rocks and groups of rocks, and their field work consisted chiefly of collecting specimens for study in the laboratory and noting local relations of the rock bodies. Cross carried on detailed geological mapping of igneous and metamorphic rocks and of the associated sedimentary rocks. His field was geological, and he studied bodies of igneous rocks as geological units formed by a geological process that was limited both in space and in time and that was somewhat variable. He was one of the first petrologists to treat successfully the components of great complex piles of volcanic rocks as a group of irregular units that could be more or less successfully mapped in much the same way as sedimentary rocks. The correlation is on the basis of age.

Cross believed strongly that scientific work, to be efficient, must be adequately supported. He wanted plenty of thin sections, chemical analysis, and a comfortable field outfit. He was not extravagant or wasteful, but knew that some misguided attempts at economy greatly reduced efficiency. He was always a strong advocate of the need to support pure science.

The field parties of Cross were training schools for young geologists, and it was a privilege to be a member of his party. He, a great field geologist, was friendly, sympathetic, generous, and patient with young men, and he was ready to listen patiently to their ideas and to keep them straight in their thinking. He had much influence on the younger men, and was a great and inspiring teacher. Many prominent geologists were his associates, including A. C. Spencer, Ernest Howe, J. D. Irving, R. D. George, G. W. Stone, Albert Johannsen, L. F. Noble, E. S. Larsen, Jr., J. C. Hunter, and C. S. Ross. The young men on the Survey looked up to Cross as a model scientist.

Cross published on the interesting potash-rich rocks of the Leucite Hills, Wyoming. He also visited the Hawaiian rocks. He published other papers on areas not near Colorado, but his main publications were on the Colorado area. He was chief of the Section of Petrology on the U. S. Geological Survey from 1903 to 1907, and secretary of the Survey's committee on petrographic names. This and his own work on rocks made the classification of igneous rocks a matter of major interest to him. Dr. Cross, Joseph P. Iddings, Louis V. Persson, and Henry S. Washington collaborated on devising a system of rock classification and in 1902 in the *Journal of Geology,* they proposed "a quantative chemico-mineralogical classification and nomenclature of igneous rocks," followed a year later by a 268-page volume on the subject. Commonly known as the C.I.P.W. system, it introduced an entirely new method of rock classification which was widely adopted, and profoundly influenced geologic thought of the world. They calculated from the chemical analysis of a rock a "norm" which was made of simple theoretical minerals such as quartz, orthoclase, albite, anorthite, leucite, melilite, hypersthen, diopside, olivine, etc., and presented a mode which represented the actual minerals of which the rock was made. The latter are mostly solid solutions or mixed crystals, and may differ in a large way from the normative minerals. A comparison of the mode and the norm of a rock is very useful and leads to a clearer understanding of the chemical history of the rock. The normative scheme is still widely used today.

Cross was a member of the group of geologists who urged upon the new Carnegie Institution of Washington the establishment of a laboratory for the study of the behavior of rocks and minerals at high temperatures and pressures. From these proposals came the Geophysical Laboratory of that Institution.

After his retirement in 1925, Dr. Cross devoted his time chiefly to the cultivation of roses, and he devoted the same rigorous, scientific methods to this study that he had earlier devoted to the science of geology. By using systematic methods, he made his garden in Chevy Chase, Maryland, a showplace. He had two thousand rose bushes, and he developed many new varieties. The outstanding new varieties he named, "Chevy Chase," "Hon. Lady Lindsay," and "Mrs. Whitman Cross."

Cross's chief recreation was playing golf. He became an expert in investment and finance, studied investments with great care, and was considered one of the most careful and successful investors in the Washington community.

At the time of his death in 1949, Dr. Cross was the oldest living member of the National Academy of Sciences and the oldest alumnus of Amherst College, from which he had received the honorary degree of Doctor of Science in 1925.

Dr. Cross was survived by Mrs. Cross, (nee Virginia Stevens), a son, Richard Stevens Cross, of Philadelphia, and two grandchildren, Charles Whitman Cross and Helen Virginia Cross.

KEY TO ABBREVIATIONS

Am. G.=American Geologist
Am. J. Sc.=American Journal of Science
Am. Nat.=American Naturalist
Colo. Sci. Soc. Pr.=Colorado Scientific Society Proceedings
G. Soc. Am. Bull.=Geological Society of America Bulletin
G. Soc. London=Geological Society of London
G. Soc. Wash.=Geological Society of Washington
Int. Geol. Con.=International Geological Congress
J. G.=Journal of Geology
Nat. Acad. Sci. Proc.=National Academy of Sciences Proceedings
Nat. Acad. Sci. Bull.=National Academy of Sciences Bulletin
Nat. Acad. Sci. Mem.=National Academy of Sciences, Memoir
Pan-Am. Geol.=Pan-American Geologist
Phil. Soc. Wash. B.=Philosophical Society of Washington Bulletin
U.S.G.S. An. Rp.=United States Geological Survey, Annual Report
U.S.G.S. Geological Atlas=United States Geological Survey, Geological Atlas
U.S.G.S.B.=United States Geological Survey Bulletin
U.S.G.S. Min. Res.=United States Geological Survey Mineral Resources
U.S.G.S.M.=United States Geological Survey Monograph
U.S.G.S., PP.=United States Geological Survey, Professional Paper
U. S. Nat. Mus. Proc.=United States National Museum Proceedings
Wash. Ac. Sc. J.=Washington Academy of Science Journal
Wash. Ac. Sc. Pr.=Proceedings of the Washington Academy of Science

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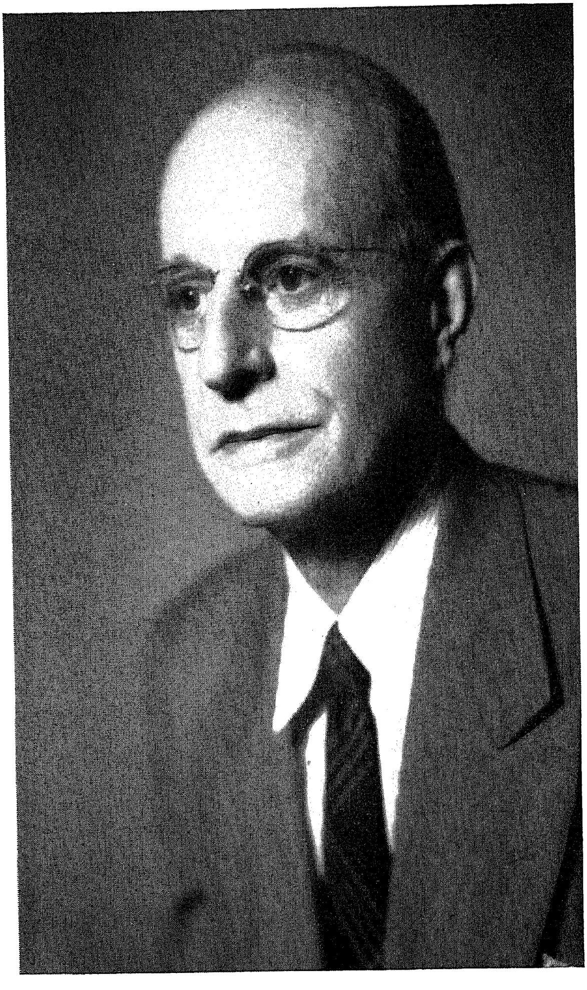

BM Duggar

BENJAMIN MINGE DUGGAR

September 1, 1872—September 10, 1956

BY J. C. WALKER

WHEN BENJAMIN MINGE DUGGAR passed away on September 10, 1956, at New Haven, Connecticut, he was well along in the seventh decade of his scientific activity. Few scientists have contributed over so long a period in so many areas of biological science.

His mother, Margaret Louisa (Minge) Duggar, was the daughter of a plantation owner in eastern Virginia. His father, Reuben Henry Duggar, was a native of central Alabama where he practiced medicine, primarily in the rural areas. He served a term of duty in the Confederate Army during the Civil War.

Benjamin Minge Duggar, the fourth of six sons, was born on September 1, 1872, at Gallion, Alabama. His secondary education was gained in the local school and under private tutors. That he was a precocious youth is shown by the fact that he entered the University of Alabama within a few days of his fifteenth birthday. After two years at that institution he transferred to the Mississippi Agricultural and Mechanical College (now Mississippi State College), near Starkville, Mississippi. This transfer would lead one to surmise that he had developed an early interest in agricultural science. As an undergraduate he assisted in the introduction of forage grasses new to the region and, by the time he was graduated in 1891, a few months before his nineteenth birthday, he had settled on the major course of his life career. He received the Bachelor of Science degree and first honors in his class. He spent the next year at Alabama Polytechnic Institute at Auburn as Assistant in Mycology and Plant Pathology to Professor George F. Atkinson, who was several years older and was soon to move to Cornell University to embark on an outstanding career in cryptogamic botany. It is significant that Duggar was to follow Atkinson to Cornell several years later to complete his Ph. D. thesis under his direction.

Duggar received the degree of Master of Science at Auburn in 1892. The subject of his Master's thesis was the germination of the teliospores of *Ravenelia*. It shows remarkably thorough, painstaking, and mature workmanship, unusual in a man only twenty years of age. During the next year Duggar was Assistant Director of the Agricultural Experiment Station at Uniontown, Alabama, where he was in direct contact with the agricultural problems of the region. In the autumn of 1893 he went to Harvard University to work under two other outstanding cryptogamic botanists, Professors W. G. Farlow and Roland Thaxter. Although he already held a B. S. and M. S. degree, he aspired to a Master of Arts from Harvard. This necessitated his matriculation in Harvard College for certain basic courses required of candidates for the M. A. degree. Having completed these, he was eligible for a Bachelor of Arts degree which was granted him in 1894. While at Harvard, he served as an assistant in botany at Radcliffe College. He completed his M. A. degree in 1895.

About this time the chinch bug was rampant on wheat in Illinois and contiguous areas. Dr. S. A. Forbes, an outstanding figure in entomology, was director of the Illinois State Laboratory of Natural History on the University of Illinois campus at Urbana. The question of fungus and bacterial parasites as means of control of the bug was beginning to receive attention. It was thus natural that Forbes should hire a promising young mycologist from Farlow's laboratory to work on this subject. Duggar was the man, but he spent only about one year as Assistant Botanist in Forbes's laboratory. Presumably he felt the need of completing his doctorate, since he was now twenty-three years of age. For this he went to Cornell and back to Atkinson. There he also became an associate and close friend of Liberty Hyde Bailey. Duggar, beginning in 1896, spent the next four years at Cornell, serving as Assistant Cryptogamic Botanist and Instructor in Botany. He completed his Ph. D. with Atkinson in 1898. His doctor's thesis was in the field of cytology. It was on the development of the pollen grain and embryo sac in *Bignonia, Symplocarpus,* and *Peltandra.* He also spent a considerable portion of his time in the chemistry department with Professors Bancroft and Orndorff. His first research in the field of physiology was concerned with germination of fungus spores. After starting this investigation at Cornell he took the problem with him to Europe (1899–1900) and completed this study in the laboratory of Wilhelm Pfeffer, the outstanding plant physiologist at Leipzig. He also worked in the laboratory of Georg Klebs at Halle and conferred with Julius Kühn, the outstanding plant pathologist at the same institution, where they exchanged their experiences with the genus *Rhizoctonia,* which Duggar had begun to study at Cornell. Returning to Cornell in the fall of 1900, he became Assistant Professor of Plant Physiology.

In 1901 he joined the staff of the Bureau of Plant Industry, United States Department of Agriculture, as Plant Physiologist. In this capacity be began studies upon cotton diseases in the South and Southwest and upon methods of mushroom culture. These investigations were continued at the University of Missouri, where he became Professor of Botany and Head of the Department in 1902, and retained a connection with the Bureau of Plant Industry as Collaborator. The cotton root rot disease was looming up as an important factor in the cotton crop which was moving steadily westward in Texas and beyond. He discovered the sporulating stage of the pathogen, on the basis of which he transferred the species from *Ozonium* to *Phymatotrichum.* He began experimental work with mushrooms, which ultimately resulted in the introduction of pure culture methods in the mushroom growing industry in this country. In 1903 he set up an exhibit on the culture of mushrooms and other fungi at the World Exposition in St. Louis, Missouri, which was awarded a grand prize. In 1905–1906 he spent fifteen months in Europe working with Professor Goebel at the Botanical Institute in Munich, with Professor Strasburger at the Botanical Institute in Bonn, and with Professor Flahault at the Botanical Institute in Monpelier. During his stay at the last institute, he participated in a botanical expedition in Algeria.

While at Cornell, he had given some attention to practical aspects of plant pathology and had begun an intensive study of *Rhizoctonia.* His interest in plant pathology continued at the University of Missouri, where he began and practically completed the manuscript of the first American textbook in plant pathology, *Fungous Diseases of Plants,* published in 1909. It remained the standard American text in the subject for many years.

In 1907 Duggar was called to the Chair in Plant Physiology at Cornell University. He remained there for five years, during which period he completed his well-known text, *Plant Physiology.* In 1912 he became Research Professor of Plant Physiology in charge of graduate work in the Henry Shaw School of Botany at Washington University and the Missouri Botanical Garden in St. Louis. It is evident from a perusal of his writings that beginning with his second stay at Cornell he became more and more interested in plant physiology. This was dictated no doubt to some extent by the nature of his position, but probably more so by the fact that he was one of those rare individuals who could not and would not narrow his interests and outlook. His interest in grasses had begun at Starkville and Uniontown; he had later been exposed to leading minds in mycology at Harvard and Cornell; but he had also been exposed to Pfeffer and others in Europe. At the turn of the century he saw in plant pathology and in mycology the opportunity and need of injecting physiology into both sciences. His ideas are expressed in a paper which he gave at a symposium on plant pathology at the annual meeting of the Botanical Society of America held at Minneapolis in December, 1910. In this address he pointed out that researches in plant pathology and in mycology had up to that time been concerned more with morphology than with physiology. He stressed the fact that "every disease produced by an organism presents the definite problem of certain complex relations between the cells of the host and those of the parasite. . . . The advancement of physiological pathology is dependent upon the work of the physiologist, of the pathologist, and of the biochemist, or upon adequate consideration of the several viewpoints which these names represent."

At St. Louis his researches broadened into various aspects of plant physiology. His research papers were concerned with such widely different topics as the development of red pigment in tomato fruits, enzymes of the red alga *Fucus vesiculosus,* nitrogen fixation, the effects of surface films on transpiration, and the application of colorimetric methods to the determination of hydrogen ion concentration in biological fluids. During the First World War, he gave particular attention to the studies of the salt requirements of higher plants. From 1917 to 1919 he served as Acting Professor of Biological Chemistry in the Washington University Medical School, in order to relieve P. A. Shaffer, who had been called into special war duties.

About 1920, when there was a rapidly growing interest among plant pathologists in virus diseases of plants, he began a study of the tobacco mosaic virus which continued for more than fifteen years. In this field he was soon recognized as a leading investigator. His researches were directed primarily toward the nature of the infective entity. He was one of the first to bring forth evidence as to the approximate size of the infective particle of the virus. He also demonstrated for the first time that the juices of certain plants, such as *Phytolacca,* inhibited the infectivity of the virus.

In 1927 Duggar was called to the University of Wisconsin as Professor of Plant Physiology and Economic Botany. In 1929 his duties were broadened to include a part-time professorship in Plant Pathology. While he gave no formal courses in plant pathology, he served as major or minor professor to many graduate students in this discipline. His broad knowledge of botany, his encyclopedic memory, his original and brilliant mind, combined with a gentlemanly, sympathetic, and helpful attitude, made for him an unrivaled position as an adviser to students and staff members in various branches of plant science.

In the late twenties there was a growing interest nationally in the biological effects of radiation. A Committee on Effects of Radiation on Organisms was formed in the Division of Biology and Agriculture of the National Research Council to bring together known information and to aid in allocation of certain research funds. Duggar served as a member of this committee. He initiated an extensive program in his own laboratory on the effects of irradiation on plant viruses and microorganisms. He also assumed the task of editing a two-volume work, *Biological Effects of Radiation,* published in 1936 under the sponsorship of the Committee. About the same time he launched with Farrington Daniels, Professor of Chemistry, a research project on quantum relations in photosynthesis in the alga *Chlorella.* He and his co-workers concluded from their experiments that the maximum efficiency with which the alga photosynthesizes in optimum environment corresponds to about 8 photons of light per molecule of oxygen evolved. This was equivalent to stored energy of about 30 per cent of the absorbed light. While this value was considerably less than that previously reported by Warburg in Germany, it has since been confirmed repeatedly in Duggar's laboratory and by most workers in this field in this country.

In his seventy-first year (1943) Duggar became Emeritus Professor at the University of Wisconsin. Still very active physically and mentally, he was not one to be easily shelved by mandatory retirement rules, especially in the midst of a devastating world war. In 1944 he accepted an appointment with the Lederle Laboratories Division of the American Cyanamid Company at Pearl River, New York, as Consultant in Mycological Research and Production. In the beginning his work here was concerned with plant sources of antimalarial drugs. The new wonder drug, penicillin, was coming into use rapidly, and streptomycin had only recently been released. Duggar was quick to see that the surface had only been scratched in the field of antibiotics. He shortly began a project which entailed a systematic search for other antibiotic-producing fungi. Thousands of soil samples were assembled and assays were conducted methodically. This project had no novice at the helm. Fifty years of experience with fungi and their physiology were focused toward a clearly defined goal. Many antibiotic-producing organisms were collected, assayed, and catalogued. But more than finding and assaying is necessary. Many biochemical and physiological tests are essential before a wonder drug is known to be effective, safe, and industrially economical. Under Duggar's leadership dozens of workers were kept busy in various laboratories and pilot plants until, within a period of about three years, *Streptomyces aureofaciens* was defined, its metabolic product, aureomycin, was isolated, and the new antibiotic with its wide applicability to human pathogens was on the production lines.

During his long career, Duggar occupied many important extracurricular positions. He was one of the organizers of the American Society of Agronomy in 1907 and served as one of the two first vice-presidents. In 1908 he served on a committee which organized the American Phytopathological Society, and served as councilor during its first year. He was vice-president of the Botanical Section of the American Association for the Advancement of Science in 1925, and of the American Society of Naturalists in 1928. He was president of the Botanical Society of America in 1923 and of the American Society of Plant Physiologists in 1947. He was granted the Charles Reid Barnes Life Membership Award by the latter society in 1941. He was president of the Society for Industrial Microbiology in 1952. When the International Congress of Plant Sciences was held at Ithaca, New York, in 1926, Duggar served as chairman of the organizing committee and as editor of the two-volume *Proceedings*. He served as editor for plant physiology of *Botanical Abstracts* during the entire period of its existence (1917–1926) and continued in the same capacity for *Biological Abstracts* from the time of its inception (1926) until 1933. He was elected to the American Philosophical Society in 1921, and to the National Academy of Sciences in 1927.

Other scientific societies of which he was a member included the Mycological Society of America; American Chemical Society; Society for Experimental Biology and Medicine; Wisconsin Academy of Sciences, Arts and Letters; New York Academy of Sciences; Torrey Botanical Club; Academy of Natural Sciences of Philadelphia; American Public Health Association; Society of American Bacteriologists; and Société Botanique de France. He was Chairman of the Division of Biology and Agriculture, National Research Council (1925–26). He was a Trustee of the Marine Biological Laboratory at Woods Hole, Massachusetts; of the Oceanographic Institute at Woods Hole; of the Bermuda Biological Station; and of the International Basic Economy Corporation Research Institute. He was a member of Sigma Xi, Phi Beta Kappa, and Phi Sigma.

Three institutions at which he had served conferred honorary degrees upon him (University of Missouri, L.L.D., 1944; Washington University, Sc. D., 1953; University of Wisconsin, D. Sc., 1956). He was given special recognition at the annual banquet of the American Phytopathological Society in 1950. As the discoverer of aureomycin his fame extended far beyond the field of plant science. He accepted speaking engagements before medical science groups in many parts of the world. He received the Medal of Honor of Public Education of Venezuela (1951); Pasteur Institute Medal (1951); Distinguished Service Medal of the Brooklyn Botanical Garden (1953); a plaque for "inquiry and improved pharmaceutical service" from the Brooklyn College of Pharmacy and Alumni Association (1954); and a Certificate of Merit from the Botanical Society of America (1956). He was elected a Fellow of the International College of Surgeons (1952). Honorary membership was conferred upon him by La Societa Italiana de Ematologia. He was made a corresponding member of La Societa Lancisiana di Roma. He was received in private audience by Pope Pius XII and given a special medal. On one of his two visits to Japan, he was invited to a private audience by the Emperor. This formal affair soon changed to a friendly informal discussion an hour or more in duration between two biologists. The next day Duggar was surprised to receive a call from the imperial messenger, who presented him with a copy of one of the Emperor's treatises on the algae.

To those who were so fortunate as to be associated with Duggar personally, he was known as a modest, friendly gentleman, slight in stature, keen in intellect, and broad in scientific and nonscientific interests. He was alert, critical, and keenly discriminating in everything he did, whether performing an experiment in his laboratory, preparing a complete southern dinner in his kitchen, or enticing a walleye or muskie to the lure on his fishing line. He had many interests. He was an expert and persistent gardener; he played tennis and golf; he loved to cook; and among his acquaintances he was recognized as an enthusiastic and expert fisherman on fresh and on salt water. He was an ardent bowler and a devoted follower of the St. Louis Cardinals when he lived in St. Louis and Madison, and of the New York Giants when he lived in New York. All of these pastimes he integrated with a busy laboratory program right up to the day of his final illness. Few persons are privileged to impress so many people in all walks of life with their sterling character and their kindly interest in humans and human affairs. Few men have left their indelible print on so many phases of biology over a period of nearly seventy years.

Dr. Duggar was united in marriage on October 16, 1901 with Marie L. Robertson of East Aurora, New York, who died in 1922. To them were born two sons and three daughters: Benjamin M. Duggar, Jr., George S. Duggar, Mrs. Charles Plunkett, Mrs. John F. Adams, and Mrs. David Saunders. On June 6, 1927, he married Elsie Rist of St. Louis, Missouri, who survived him. To them was born one daughter, Gene Lorraine Duggar. All of his children and thirteen grandchildren survived him.

KEY TO ABBREVIATIONS

Ala. Canebrake Exp. Sta. Bull. = Alabama Canebrake Experiment Station Bulletin
Am. J. Botany = American Journal of Botany
Ann. Mo. Bot. Garden = Annals of the Missouri Botanical Garden
Ann. N. Y. Acad. Sci. = Annals of the New York Academy of Sciences
Ann. Rev. Biochem. = Annual Review of Biochemistry
Biol. Bull. = Biological Bulletin
Botan. Gaz. = Botanical Gazette
Bull. Ill. State Lab. Nat. Hist. = Bulletin of the Illinois State Laboratory of Natural History
Bull. Torrey Botan. Club = Bulletin of the Torrey Botanical Club
Carnegie Inst. Wash. Yearbook = Yearbook of the Carnegie Institution of Washington
Cornell Univ. Agr. Exp. Sta. Bull. = Cornell University Agricultural Experiment Station Bulletin
J. Agr. Res. = Journal of Agricultural Research
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Bacteriol. = Journal of Bacteriology
J. Cancer Research = Journal of Cancer Research
J. Cellular and Comp. Physiol. = Journal of Cellular and Comparative Physiology
J. Phys. Chem. = Journal of Physical Chemistry
N. Y. State Agr. Exp. Sta. Tech. Bull. = New York State Agricultural Experiment Station Technical Bulletin
Proc. Amer. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
Proc. Amer. Phil. Soc. = Proceedings of the American Philosophical Society
Proc. Amer. Soc. Hort. Sci. = Proceedings of the American Society of Horticultural Science
Proc. Intern. Cong. Plant Sci. = Proceedings of the International Congress of Plant Sciences
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences of the United States of America
Proc. Soc. Amer. Florists = Proceedings of the Society of American Florists
Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine
Proc. Soc. Hort. Sci. = Proceedings of the Society of Horticultural Science
Proc. Soc. Promotion Agr. Sci. = Proceedings of the Annual Meeting of the Society for the Promotion of Agricultural Science
Trans. Acad. Sci. St. Louis = Transactions of the Academy of Science of St. Louis

Trans. Mass. Hort. Soc. = Transactions of the Massachusetts Horticultural Society

U. S. Dept. Agr. Bur. Plant Indus. Bull. = United States Department of Agriculture Bureau of Plant Industry Bulletin

U. S. Dept. Agr. Farmers' Bull. = United States Department of Agricultural Farmers' Bulletin

Wash. Univ. Studies = Washington University Studies

Zentr. Bakteriol., ·Parasitenk. = Zentralblatt für Bakteriologie, Parasitenkunde, Infektionskrankheiten und Hygiene

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CLARENCE EDWARD DUTTON

May 15, 1841—January 4, 1912

BY CHESTER R. LONGWELL

SCIENTIFIC EXPLORATION "west of the hundredth meridian," interrupted in its early stages by the Civil War, was resumed promptly with the return of peace. Ferdinand Hayden and Clarence King led off with ambitious programs, and a significant recruit, John Wesley Powell, began his constructive public service in 1869 with the first exploratory trip down the Colorado River of the West. The grim experiences of the war years matured and hardened Powell and some of his potential assistants for the rigorous labors involved in field study of a rugged, sparsely settled country. One destined to become a top-flight assistant and colleague was Clarence Edward Dutton, now identified in standard biographies as "soldier and geologist."

Dutton was born May 15, 1841, at Wallingford, Connecticut, where his father was a shoemaker and also served for many years as postmaster. Clarence had much of his early schooling at Ellington, Connecticut, and advanced so rapidly that he could have gone to college at the age of fourteen. He was held back for a year, then entered Yale College and was graduated with the class of 1860, shortly after his nineteenth birthday. His early intention, encouraged by his family, was to fit himself for the ministry, but continued study and maturing judgment brought conviction that his real interests were in other fields. Literature attracted him strongly, as evidenced by his winning the "Yale Lit" medal in his junior year. Macaulay's essays fascinated him, and Thackeray was his favorite novelist. Doubtless

C. E. Dutton

his early absorption in good literature bore fruit in the style of his own later writings.

Dutton's enthusiasm for learning did not make him an unbalanced, ascetic individual. He had a fine physique, and as an undergraduate he became an outstanding athlete, particularly in gymnastics and in rowing. In later years he liked to recall that he rowed No. 7 in the first crew race between Yale and Harvard. A sturdy constitution was later an essential asset when he engaged in long seasons of geologic work, traveling on horseback and afoot in the western plateaus and canyons.

Dutton continued at Yale in graduate study for two years after receiving the B. A. degree. Whether James Dwight Dana may have planted the seed that later grew into his flair for geology is not known. Certainly mathematics and chemistry came to share a place with literature in his broad range of interests. Clarence King, his junior by a year and later one of his chief associates, was graduated from the Sheffield Scientific School in 1862, but perhaps the two did not meet as students—"Sheff" and "Ac" were close neighbors physically, but at that date they were essentially separate institutions.

The war became a pressing reality, and in September, 1862, Dutton enlisted in the Twenty-first Connecticut Infantry and was appointed adjutant, with rank of first lieutenant. His unit saw early action, and he was wounded at the battle of Fredericksburg, but stayed with his regiment, recovering to take part in the battle of Suffolk and in many minor skirmishes. In March, 1863, he was promoted to the rank of captain. Later the same year he passed an examination given by the Ordnance Corps of the regular army—an exceptional accomplishment for one without West Point training—and in January of 1864 he accepted appointment as second lieutenant of ordnance. In the last year of the war he commanded the ordnance depot of the Army of the Potomac.

When the war ended he kept his army assignment, and early in 1867 he was promoted to be first lieutenant. Apparently he liked the ordnance work, his position gave him and his growing family security and—probably an important determinant—it afforded some leisure and facilities for further study in scientific fields. For several years he devoted time to study of geology and to certain aspects of chemistry. A revolution in the manufacture of steel was under way, and in 1869, while Dutton was stationed at the Watervliet Arsenal, West Troy, New York, he read before the American Association for the Advancement of Science his first scientific paper, "On the Chemistry of the Bessemer Process."[1] His transfer the following year to the Frankford Arsenal, Philadelphia, placed him within the congenial orbit of the Franklin Institute, the American Philosophical Society, and the Academy of Sciences. At a meeting of the Philosophical Society he presented a paper, "The Causes of Regional Elevations and Subsidences," which reveals that he had already given some thought to profound geologic problems, though he was barely thirty years old and his military duties had first call on his time and energy.

The stay in Philadelphia was brief. In 1871 he was transferred to the arsenal at Washington, D. C., just in time to witness the struggle among rival groups of geologists that finally was resolved by the establishment of the U. S. Geological Survey in 1879. He joined the Philosophical Society of Washington, where he met distinguished men in various fields of learning; his love for literature remained strong; and he maintained a broad interest in science. During his long residence in Washington, he associated freely with leaders in the sciences and arts, professionally through the learned societies, socially through the Cosmos Club, in the founding of which he played a part. When Dutton moved to Washington, J. W. Powell was away, directing the second trip down the Colorado River and planning an ambitious program of mapping in the plateau country. Probably he and Dutton met in 1872, and their acquaintance soon became firm and intimate. The two were long known among their acquaintances as "the Major" and "the Captain," Powell carrying the former title from his Civil War service and Dutton acquiring the rank Captain of Ordnance by promotion in 1873. Dutton usually referred to Powell as "Professor," a title derived from Powell's teaching experience in Illinois.

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[1] Only the title of this paper was printed in the *Proceedings* of the Association for 1870.

In maturing plans for further geologic studies in Utah Territory, Powell became convinced that Dutton was the man best equipped to have charge of the field work. For some time Dutton demurred, but the prospect was attractive to him, and in 1875 the Ordnance Corps agreed to detach him temporarily for detail to the Survey of the Rocky Mountain Region under the Interior Department. This assignment began for him a fifteen-year period of phenomenal activity and achievement.

When Dutton was detailed by the Ordnance Corps for geologic work, he felt he was in some respects a novice among the more experienced field workers, and he cultivated their acquaintance and counsel. A favorite colleague was G. K. Gilbert, who had begun his far-western work with the Wheeler party in 1871. Gilbert started his historic study of the Henry Mountains in 1875, and so shared with Dutton the beginning of systematic mapping in the plateau country near the Grand Canyon. A brief report by Dutton on some of the igneous rocks collected in the Henry Mountains is included in Gilbert's monograph, *Geology of the Henry Mountains,* published in 1877. J. W. Powell shared with Gilbert a high place in Dutton's esteem, and during the winter months in Washington the three were often together for comparison of notes and discussion of problems relating to the plateaus. Dutton testified that these friendly consultations had benefited him immeasurably, and in a published acknowledgment to Powell and Gilbert he stated, "If I paid them their intellectual dues I would be bankrupt."

Powell, Gilbert, and Dutton together laid a firm foundation on which rests much of our present understanding of geologic history as it is revealed in the unexcelled exposures of the wide Colorado Plateau. In considerable part their published records and conclusions have been superseded by results of later, more detailed work. Inevitably the first reconnaissance of an area so immense and rugged, by a few trained men who lacked equipment now considered indispensable, gave results that by modern standards are somewhat crude and in part erroneous. But some basic conclusions set down by these early workers mark them as men of exceptional initiative and vision. Powell, in his introduction to Dutton's report on the High Plateaus, reveals that at that early stage in study of the sedimentary rocks the evidence of earlier highlands to the west had been detected. Gilbert's report on igneous bodies of the Henry Mountains remains a classic with international recognition. Dutton's attention was focused particularly on the evidence for differential uplift of crustal blocks, and on the major role of erosion in fashioning the Grand Canyon and other surface features of the plateau country. He recognized evidence for two major episodes of erosional history: the first he called "the great denudation," the second "the canyon cycle." With Gilbert and Powell he did much to stimulate ideas on the systematic development of land forms.

Geologists who have some present-day acquaintance with the high-plateau country of southcentral Utah can have only the highest admiration for the results accomplished there by Dutton and his party in three summers of field work. Much of the country is extremely rugged, and in the 1870s practically all of it was difficult of access. Settlements were restricted to widely spaced valleys, the only railroad was far to the north, and the means of travel for men and supplies was restricted to team and wagon, pack train, and saddle horse. Formidable relief increased the physical difficulties; several of the large plateaus have altitudes well above 11,000 feet, and from their cliffy margins steep slopes extend into nearby valleys several thousands of feet lower. And Dutton was faced not only with unknown geology—the geography of this region also was in a nebulous state. Base maps were a first essential.

Because of high altitudes, the winters in the high plateaus are long and seasons for productive field work are short. Yet from 1875 to 1877 Dutton's party mapped an area measuring about 150 miles long from north to south, 50 miles wide at the north and 110 miles wide at the south—fully 12,000 square miles—on a scale of 4 miles to the inch. A. H. Thompson, who had been with Powell on both trips down the Colorado, established the triangulation net for control, and two skilled topographers equipped with plane tables sketched the chief physical features on sheets with contours spaced at intervals of 250 feet. On this base Dutton represented the geology: the sedimentary rocks by systems, Carboniferous to Quaternary, and the igneous rocks classified in four categories. The result is of course a first approximation, and Dutton himself was acutely conscious of the deficiencies. But the aim was to present a broad picture of the geography and geology of that little-known region as quickly as possible. Time was cut to a minimum not only in the field study, but also in arrangements for publication. Less than three years after the third field season was complete, the Government Printing Office was distributing a quarto volume of 307 pages filled with Dutton's clear descriptions and explanations, accompanied by an atlas, measuring 22 x 32 inches, made up of well-executed maps and structure sections. This work was received with enthusiasm both in this country and abroad; more than one competent critic gave it emphatic approval.

Dutton became more and more fascinated by the Grand Canyon country, directly south of his high plateaus. He made brief excursions along the lower belt near the canyon late in the season, after the high region grew too cool for comfort, and on completion of the high-plateau project he devoted three seasons to a comprehensive study of the Grand Canyon geology. While this work was in progress, the U. S. Geological Survey was organized, with Clarence King as its first Director. Dutton's Grand Canyon work was one of the first projects to be completed and published by the new organization. Again both Dutton and the publishers were prompt; field work ended in 1880, and two years later two large reports were in print. One of these, comprising about 120 pages with plates and figures, appeared in the second *Annual Report* of the Geological Survey; the other, consisting of a quarto volume with 264 pages, accompanied by a large atlas, is Monograph 2 of the Survey, but actually the first of the monographs to be published.

The latter work remains an outstanding classic of geology. Inspired descriptions of the Canyon landscape are reinforced with fine panoramic drawings by W. H. Holmes. Dutton found the Canyon country "a great innovation in modern ideas of scenery, and in our conceptions of the grandeur, beauty, and power of nature." Living for weeks with the grand panorama spread before him, seeing the subtle variations in color, outline, and composition as light values changed with the height of the sun, he came to feel that the scientific and esthetic qualities of the canyon landscapes were inseparable and that "the severe ascetic style" of ordinary description could not do the subject justice. Accordingly, a part of his report is a sort of guided tour in which choice parts of the Canyon scenery are exhibited to the reader through Dutton's experienced eyes. Readers who may feel that parts of the description are overdrawn should spend a few hours at one of Dutton's viewpoints, such as Point Sublime, to appreciate the judgment of the British geologist, Archibald Geikie, who said after reading Dutton's monograph: "Any man who could sit down and dissect these cañons in cold blood, and with as little emotion as he would show in cutting up a joint of beef, would be a creature not to be envied."

Abundant volcanic rocks in the plateaus drew Dutton's attention to volcanism as a major geologic problem, and in 1882 he spent six months in a field study of Hawaiian volcanoes. True to his habit, he put his findings and resultant ideas into print, this time in several short papers, besides a lengthy report published by the Survey. Meanwhile, he resumed field study in the plateaus, spending two seasons in the extinct volcanic field around Mount Taylor, New Mexico, and the adjacent Zuñi uplift. With volcanism still uppermost in his interest, he began a survey of the Cascade Range in Oregon and northern California, but before the end of his second season there his attention was diverted by the earthquake of 1886 at Charleston, South Carolina. Intensive study of that event and its effects resulted in a major publication, as well as shorter papers on earthquakes in general.

Dutton was elected to the National Academy of Sciences in 1884.

Dutton's publications up to this point assured him wide recognition in geology, but probably his name is best known because of a short paper, published in 1889, entitled, "On Some of the Greater Problems of Physical Geology." An early essay, published before his transfer to Washington, revealed his concern about the basic reasons for large-scale uplift and subsidence of the earth's surface. During his studies in the plateau region, he had been impressed with eloquent examples of such movements: wide plateau blocks, floored with sedimentary rock formed in the sea, now thousands of feet above sea level; the Front Range of Colorado and other Rocky Mountain units, all once below the sea and now thousands of feet higher than adjacent plains and plateaus. Long reflection on these facts led him to favor the concept of a general balance within the earth's crust, with lighter weight blocks coming to stand higher than adjacent blocks with higher density. For this concept, first expressed by Pratt and Airy in the 1850s, Dutton now proposed the term *isostasy,* "equal-standing," a term that has met world-wide acceptance.

In 1890, when the many and diverse projects he had undertaken for the Geological Survey were completed, Dutton was returned to military duty upon his own request. The next year he was advanced to the rank of Major and placed in command of the San Antonio (Texas) Arsenal, where he remained for eight years. Early in 1901 his application for retirement was granted, but his interest in geology and related subjects continued unabated. He had kept abreast of rapid developments in seismic study, and in 1904 he published a book on which he had worked for years, *Earthquakes in the Light of the New Seismology*. The discovery of radioactivity, announced while he was on duty in Texas, fired his imagination. Could radioactive heat be the basic cause of volcanic activity? This concept was embodied in a paper, "Volcanoes and Radioactivity," published in 1906.

His last years were spent in the home of his son at Englewood, New Jersey. Failing health took away much of his energy, but not his interest in scientific developments and writings. Arteriosclerosis made rapid inroads, and he accepted calmly the certainty that the end was near. One of his last comments was, "Farewell to my old friends on the Geological Survey." He died peacefully on January 4, 1912, in his seventy-first year.

Dutton's immediate family was small. He married, April 18, 1864, Emeline C. Babcock, of New Haven, Connecticut. They had a son, Clarence Edward, Jr. Their only daughter had passed away nine years earlier. No member of the family is now living.

Surely this man's career was exceptional, and a considerable part of his published results has lasting value. Few professional geologists have within a span of fifteen years done as much constructive scientific work; yet his contribution was made outside his official position in the regular army. His publications are an enduring testimony to his scientific and literary abilities, and fortunately some intimate associates have set down impressions of his personality and character.

Dutton was an attractive person, with erect carriage and powerful physique. Beards were popular in his day, and published photographs show him with large moustache and small chin whisker. Ordinarily he was reserved and unassuming, but always friendly, interested in all kinds of people, and an excellent conversationalist. He read rapidly and widely, had an exceptionally retentive memory, and was well informed on current as well as historical matters and on good literature. Intricate problems fascinated him, and in their solution he showed remarkable powers of concentration. From an early age he liked chess, and sometimes he played as many as seven simultaneous blindfold games. Occasionally he would spend an entire night wrestling with a chess problem, finally laying it aside to join the family at breakfast. This kind of diversion went logically with his love of mathematics and science. During these absorbing games, as well as in period of serious study, he smoked prodigiously.

But when he was about fifty years old he gave up chess as an interference with his work, and a few years later he stopped smoking, convinced that it was injuring his health.

The son, Clarence E. Dutton, Jr. has set down some information that helps explain the large volume of his father's contribution within a few years. An important part of the explanation lies in the elder Dutton's early mastery of literary analysis and composition. "The literary side was first cultivated and its expression fixed before he turned to science." In preparing a report, "the subject at hand was always mentally laid out in practically final form before he began writing. Most of it he wrote out, and there were few changes made. For several years I was his amanuensis and typed his papers as he dictated; little had to be rewritten. . . . In one (very long) working day he dictated to me over 11,000 words. There were two minor corrections only. . . . I was so familiar with his expression that I could usually catch up with him, if he spoke fast, at the end of a sentence. If I failed, he would repeat the entire sentence without hesitation, no matter how long."

Preparation of an adequate biographical sketch nearly half a century after Dutton's death has not been an easy task. For much of the required basic information I am indebted to the Alumni Records of Yale University, and to the generous help of two people whose researches have been concerned with J. W. Powell and his professional associates: Professor Wallace Stegner of Stanford University, and Professor Thomas G. Manning of Texas Technologic College.

KEY TO ABBREVIATIONS

Am. Jour. Sci. = American Journal of Science
Ann. Rpt. = Annual Report
Bull. Phil. Soc. Wash. = Bulletin of the Philosophical Society of Washington
Congrès Internat. = Congrès International
Geol. Mag. = Geological Magazine
Internat. Cong. Geol., Am. Comm. Rpts. = International Geological Congress, Reports of the American Committee
Jour. Geol. = Journal of Geology
Mon. = Monograph
Penn. Monthly = Pennsylvania Monthly
Pop. Sci. Monthly = Popular Science Monthly
Proc. Am. Assoc. Adv. Sci. = Proceedings of the American Association for the Advancement of Science
Proc. Am. Phil. Soc. = Proceedings of the American Philosophical Society
Senate Misc. Doc., 52nd Cong. = Senate Miscellaneous Documents, Fifty-second Congress
U. S. Geog. and Geol. Survey = U. S. Geographical and Geological Survey
U. S. Geog. and Geol. Survey Terr. = U. S. Geographical and Geological Territorial Survey
U. S. Geol. Survey = United States Geological Survey

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HAROLD HIBBERT

August 27, 1877—May 13, 1945

BY MELVILLE L. WOLFROM

HAROLD HIBBERT was born in the textile center of Manchester, England, on August 27, 1877, to Martha (Scholes) and Isaac Hibbert, both of Manchester, as the second in a family of four boys. His father held a responsible position with a Manchester company engaged in the export of cotton goods, mainly to South America. Isaac Hibbert (1844–1914) was active in the United Methodist Church of Manchester and was a staunch and devoted Liberal; he was a teetotaler, a nonsmoker, played the violin, had a good tenor voice, and was able to converse in Spanish. Harold was raised in the stimulating atmosphere of this fine home and his talents were early recognized when at the age of seventeen he was awarded a Manchester Corporation Scholarship which enabled him to enter the Victoria University of Manchester. This university, now generally known as Manchester University, was chartered in 1880 and had developed from the privately endowed Owens College, opened in 1851. Harold elected the Honours course and graduated in 1897 with First Class Honours in Chemistry. William H. Perkin, Jr., then near his fortieth year, was Professor of Chemistry at Manchester and was attracting many research students. Hibbert was awarded the fellowship known as the Levinstein Exhibition for research in organic chemistry and received the M. Sc. degree under Perkin in 1900. This contact with Professor Perkin, an outstanding investigator in organic chemistry, greatly stimulated the young man, and Perkin was the

Harold Hibbert

first of three great leaders in this discipline to exert a marked influence upon Hibbert's career.

Hibbert accepted an appointment, in 1899, as Instructor in Chemistry at the University College of Wales, Aberystwyth. In support of his student, Perkin had written: "I have no hesitation in expressing the opinion that Hibbert has every prospect of a very successful career before him." North Wales is in many ways more closely related to Lancashire and the Midlands than to South Wales; its university was opened in 1872 and chartered in 1892. In 1901 J. J. Sudborough was appointed Professor of Chemistry, and Hibbert's first publications, as joint author with Sudborough, were concerned mainly with applications of the Tschugaeff (Zerewitinoff) reaction, then quite new. Hibbert remained in this post until 1904, when he left for further study at the University of Leipzig.

He arrived in Leipzig in October, 1904, and worked under Arthur Hantzsch, who had just succeeded Johannes Wislicenus. The research outlook of Hantzsch was mainly physicochemical in nature and Hibbert's work with him concerned addition products of trialkyl derivatives of phosphines, arsines, and stibines. The starting materials were prepared by the Grignard reaction rather than by the use of zinc alkyls. The University of Leipzig awarded Hibbert the Ph. D. degree *summa cum laude* in 1906. Professor Hantzsch was a scholar and philosopher and his lectures in organic chemistry, accompanied by numerous experiments, were highly inspirational. Hibbert's natural charm and cordial manner and his sincere respect for his professor brought him into intimate contact with Hantzsch and his family, a distinction allotted to but few other students. Hantzsch was an ideal host, well versed in art, poetry, and music. At Leipzig, Hibbert became acquainted with a small group of American students who later became distinguished chemists in their homeland—W. C. Bray, Colin G. Fink, Arthur B. Lamb, and S. C. Lind. Hibbert valued and maintained their friendship, and in later years he was to have the honor of presenting the Perkin Medal of the American Section of the Society of Chemical Industry to Colin G. Fink, distinguished for his researches in the electroplating of chromium. While in Germany, Hibbert learned to speak the German language with an idiomatic ease that remained with him throughout his life. Memories of this period must have been vivid to him during the celebrated "Gemütlicher Abend" of the 1938 Milwaukee Meeting of the American Chemical Society. Here we find him surrounded by his own students, singing heartily the German songs of his student days.

Following the Leipzig period, Hibbert accepted a postdoctroal appointment in the United States with Arthur Michael at Tufts College of Boston, Massachusetts, and remained there for two years, 1906 to 1908. The vigorous personality of Michael made a powerful impression upon him and greatly influenced the subsequent course of his career. Hibbert worked with Michael on keto-enol tautomerism and studied especially the role of the solvent in this equilibrium. It is of interest to note that the discussion of their published work occupies a full page in the monograph of F. Henrich, *Theories of Organic Chemistry,* published in 1921.

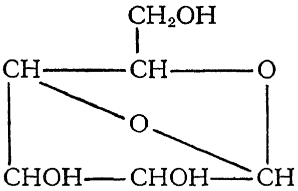
Hibbert returned to England in 1908 and researched for a little over a year at the Imperial College of Science in London, under a Chemical Society grant and in association with Sir William Tilden. Here he completed work begun previously at Aberystwyth and concerned with some quantitative applications of the Grignard reaction now known at the Tschugaeff-Zerewitinoff method. The usefulness of a high-boiling ether in this reaction had been demonstrated by Sudborough and Hibbert in 1904, and they were the first to employ the procedure in a quantitative fashion. Hibbert presented some of this work at the February 18, 1909, meeting of the Chemical Society in London, and introduced the term "affinergy" as a substitute for Michael's "chemical potential," a proposal vigorously criticized by Arthur Lapworth and Sir William Ramsay in the subsequent discussion.

The English degree of D. Sc. corresponds to the Dr. Habil. (Doktor Habilitation) of the German universities, and the D. Sc. degree was conferred upon Hibbert in 1912 by the Victoria University of

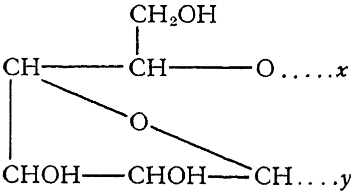
Manchester. Disappointed in his efforts to obtain an academic appointment in Great Britain, Harold Hibbert returned to the United States and entered the chemical industry of this country. During the period from 1910 to 1914 he was a research chemist at the Experimental Station of the E. I. du Pont de Nemours Powder Co. at Wilmington, Delaware. At the time this great company was essentially a manufacturer of explosives and Hibbert published important work on the practical and theoretical significance of the dimorphism of glycerol trinitrate (nitroglycerin).

In 1914, after the outbreak of war in Europe, Hibbert became a Fellow of the Mellon Institute for Industrial Research at Pittsburgh, Pennsylvania. He worked on the synthesis of glycols and on new methods for the synthesis of acetaldehyde and acetic acid from acetylene. He published his famous procedure for dehydrating alcohols with a trace of iodine and presented a rational explanation for it. In association with Benjamin T. Brooks, he published a method for the synthesis of a "fusel oil" from petroleum. The large outlet for ethylene glycol as an antifreeze material in automobile cooling systems received its start in 1917, when Hibbert obtained United States Patent 1,213,368 relating to the use of ethylene glycol for lowering the freezing point of water in automobile cooling systems; he demonstrated the suitability of ethylene glycol dinitrate as a liquid explosive. In 1916 Hibbert left the Mellon Institute to enter private consulting work in Toronto and later in New York City. He was Chemical Adviser (on gas warfare) to the British War Mission in Washington, D. C., during 1917 and 1918. He served as Director of the Research and Technical Division of Ralph L. Fuller and Co., New York, N. Y., a company organized for the manufacture of such wartime-needed pharmaceuticals as salicylic acid and phenacetin. During this period he published a number of articles on general industrial chemistry, including a significantly prophetic one on the need for more attention to the aliphatics on the part of the organic chemical industry.

In 1917 he had married Beulah Virginia Cole, then a teacher of physiography in the Julia Richman High School of New York City, and much of his success was due to her guidance and inspiration. By the end of the First World War, and at the age of forty-two, he had the courage to change abruptly his plan of life. He abandoned the more lucrative career of an industrial chemist and in 1919 accepted an appointment as Assistant Professor of Chemistry at Yale University. Here he initiated his series of publications entitled "Studies on Reactions Relating to Carbohydrates and Polysaccharides." Utilizing the finding of Denham and Woodhouse that methylated cellulose yields 2,3,6-tri-*O*-methyl-D-glucose on hydrolysis, Hibbert proposed the following formula for the cellulose monomer.

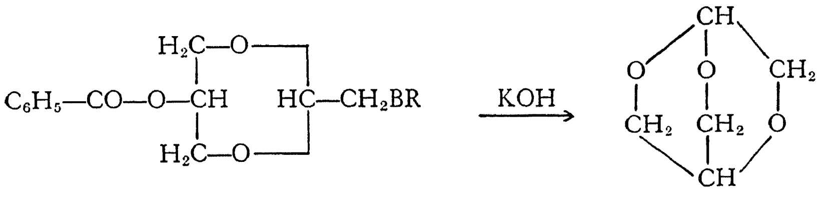


In accord with the viewpoint of the time, the polymerization could occur by association through secondary valence forces, but Hibbert discussed, and did not exclude, the possibility that the monomers might form a main valence polymer by an opening of the 1,5-oxygen bridges as shown,



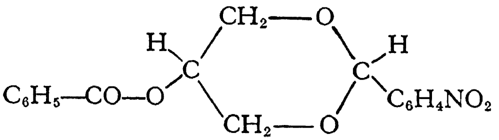
x and *y* being similar monomers.

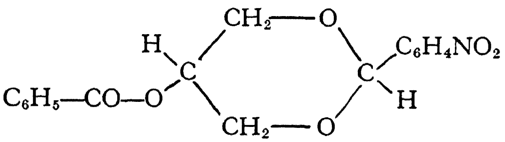
He next attempted to synthesize analogs of the monomeric unit of the above structure from simple substances. While he and his students were unsuccessful in this endeavor, they did unearth a very considerable body of information concerning the formation and reactivity of cyclic acetals. It was found that 5-hexanone-1,2-diol polymerized in the presence of a trace of acid, and this change was considered analogous to the suggested transformation of D-glucose into cellulose. Chloral was shown to combine readily with simple aliphatic aldehydes to form polymers of the general type $(2RCHO + Cl_3CCHO)_X$. Treatment of 1,3-*O*-(2-bromoethylidene)-glycerol benzoate with alkali yielded the crystalline bicyclic acetal I.



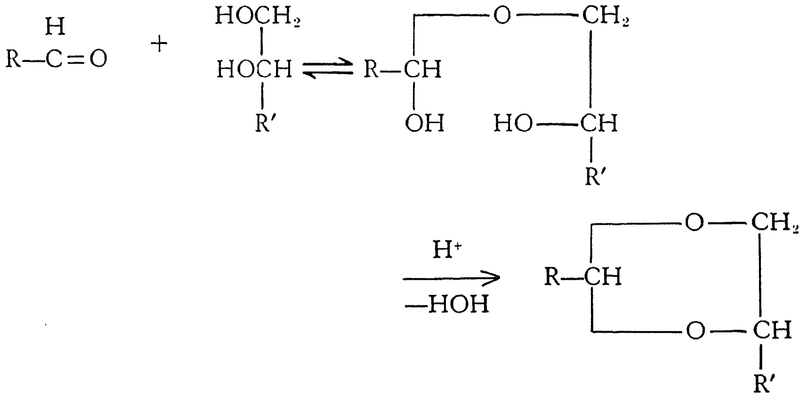
I

The reaction between glycerol and benzaldehyde was shown to result in a partition between five- and six-membered cyclic acetals, thus eliminating the necessity of vicinal hydroxyl groups for condensation. In the case of the corresponding six-membered *p*-nitrobenzylidene acetals, an equilibrium ratio of 0.4:1, favoring the five-membered isomer, was obtained under defined acidic conditions. In alkaline media, on the other hand, no tendency toward ring shift was observed, thus indicating the reliable nature of the methylation process employed in the proof of sugar glycosidic ring structures. 1,3(and 1,2)-*O*-(*p*-Nitrobenzylidene)-glycerol 2(and 3)-benzoate were each obtained in the two isomeric forms predictable on stereochemical grounds.



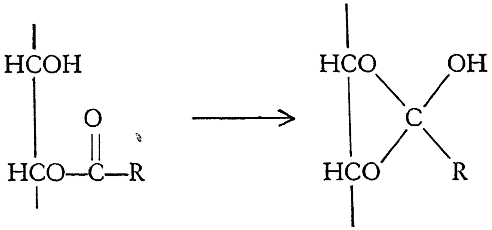


The reaction of acetone with the polyhydroxy compounds employed by Hibbert and his associates always resulted in the exclusive formation of the five-membered cyclic acetal. The course of all these condensations was shown to be stepwise, with the intermediate product being isolated in several cases.

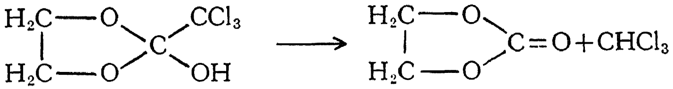


The ease with which the initial reaction took place was a function of the polar character of the carbonyl group, increasing with halogen substitution in the R-group. The ease of ring formation, on the other hand, was found to follow the reverse order, as did the ratio of the six- to the five-membered cyclic acetals.

Significant work was carried out on the nature of acyl group migration. Following a suggestion of Emil Fischer, Hibbert considered that the orthoester or dioxolane ring structure was the intermediate.



He showed that in glycerol esters the migration was toward the primary hydroxyl group. He stated, "The tendency and ease of ring formation will be dependent on: (a) the relatively labile character of the hydrogen attached to the hydroxyl group, (b) the negative polarity of the carbonyl group in the acyl radical, and (c) the spatial relationship of the migratory hydrogen atom with reference to the carbonyl group." His prediction that the orthoester structure would be stabilized by the trichloroacetyl radical was verified by the finding that the trichloroacetate of ethylene glycol existed only in the cyclic form; when this substance was heated, it decomposed into chloroform and the carbonate.

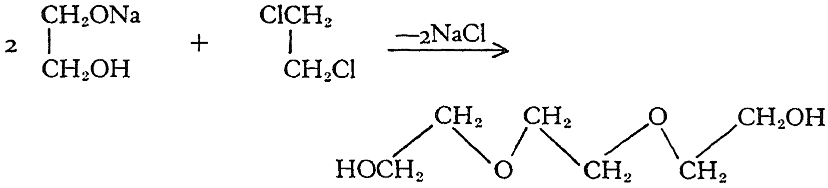


On the other hand, the methyl ethers showed no tendency to migrate and the reaction RCl → ROMe was effected without migration. These early studies on "neighboring group effects" are outstanding contributions to the science of organic chemistry and to the specific interpretation of carbohydrate reactions.

Harold Hibbert was the impelling force in the founding, in 1920, of the Division of Cellulose Chemistry of the American Chemical Society; his associates in this effort were G. J. Esselen, Jr., H. LeB. Gray, L. F. Hawley, Bjarne Johnsen, and L. E. Wise. Hibbert served as Chairman of the Division from 1920 to 1922. One of its first activities was the establishment of procedures to define a Standard Cellulose preparation. Hibbert was always to be found in attendance at the meetings of the Cellulose Division, where he acted as a vigorous and stimulating leader of the discussions. Later he was joined in this endeavor by Emil Heuser. The meetings of the Cellulose Division were never dull in those times.

In 1925 Hibbert left Yale University to become the E. B. Eddy Professor of Industrial and Cellulose Chemistry at McGill University, Montreal, Quebec, Canada, and he remained there for eighteen years until his official retirement in 1943. He had become a citizen of the United States in 1923 and he maintained this status during the remainder of his life, even though most of it was spent in Canada. McGill University, where the Pulp and Paper Research Institute of Canada had just been completed, offered an unparalleled opportunity for research, which he embraced with great vigor. Hibbert possessed an abundance of energy and an enormous capacity for work. He contributed greatly to the establishment of graduate scientific study in the universities of Canada both by his own efforts and by those of the men he trained. He was an inspiring taskmaster to the more than one hundred predoctoral and postdoctoral students who came to him from all parts of the Dominion and from other countries. He taught them to work hard and to like it. His enthusiasm and vision gave life and meaning to many an otherwise tedious investigation. His own valuable library was always available to them; he planned with them for their future; he never rested until he had found a place in industry, a grant—often out of his own pocket—or a teaching position for each of "his boys" (and several "girls"). Mrs. Hibbert felt an equal concern for the welfare of the students.

After Wallace H. Carothers and Hermann Staudinger had established the nature of polymers on the firm basis of primary valence concepts, Hibbert and his associates made a definite contribution by synthesizing a series of individual linear polymers of known chain-length and studying their properties as a function of this linear size. The fundamental reaction employed is illustrated below.

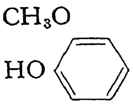


By this method there was prepared the series members with degrees of polymerization of 4, 6, 8, 12, 18, 42, 90, and 186 units.

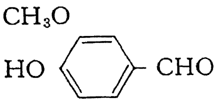
He studied the preparation and properties of the polymeric "humic acid" formed by the action of mineral acids on hexoses. The product for a time found use as an extender in lead storage batteries.

Hibbert was intrigued by the polysaccharides elaborated by the slime-producing bacteria, and he and his associates carried out pioneer studies on their chemical nature. The membrane grown by *Acetobacter xylinum* was shown to be cellulosic, and at the same time the general chemical identity of wood cellulose and cotton cellulose was demonstrated. Pioneer investigations were carried out on the nature of the glucan produced by various strains of *Leuconostoc mesenteroides*. The main linkage present was shown to be α–D-(1 → 6). These investigations were later considerably elaborated in other laboratories when this material became of interest as a blood extender. The bacterial fructans known as the levans were shown to be isomeric with inulin in that the linkage present between the D-fructofuranose units was (2 → 6) instead of the (2 → 1) of inulin. Considerable attention was given to the nature of the carbohydrates utilizable by the organisms concerned.

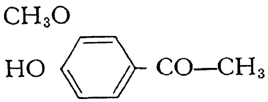
Wood chemistry was naturally a major concern of the Pulp and Paper Research Institute of Canada, and Hibbert studied, with his associates, the action of alkali on cellulose and the complex reactions concerned in the oxidation of cellulose. An intensive study was made of the pulp bleaching process and of the manufacture of vanillin from pulping waste liquors. Professor Hibbert, however, placed his main emphasis upon lignin, publishing eighty-seven papers in the series entitled "Studies on Lignin." The Hibbert laboratory examined the action of alkalies on lignin sulfonic acids and showed that the soft woods (such as spruce) were characterized by the lignin alkaline degradation products, I, II, and III and the hard woods (such as maple) by the analogous products IV, V, and VI.



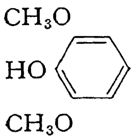
I
Guaicol



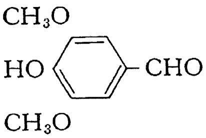
II
Vanillin



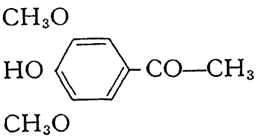
III
Acetovanillin



IV
Pyrogallol 1,3-dimethyl ether

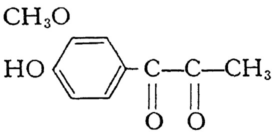


V
Syringaldehyde

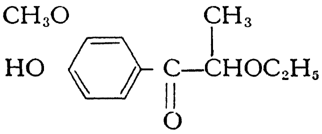


VI
Acetosyringone

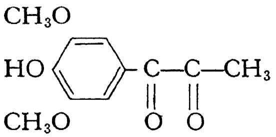
They also investigated the water-soluble fraction obtained in the extraction of lignins (such as maple ethanol lignin) from wood meal (previously extracted to remove fats, waxes, resins, and tannins) by the action of alcohols in the presence of acids. They identified the products VII to X.



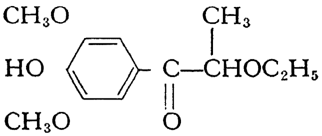
VII
Vanilloyl methyl ketone



VIII
α-Ethoxypropiovanillone



IX
Syringoyl methyl ketone



X
α-Ethoxypropiosyringone

Substances VIII and X were considered to be ethyl ethers formed in the ethanolysis reaction from the hydroxyl compounds originally present; VIII and X are derivatives of the class of compounds known as benzoins which are characterized by their ease of polymerization. The products VII to X establish the C_6—C—C—C building units of lignin and have come to be known as the Hibbert *Bausteine* (building stones). How they are combined in the complex lignin polymer is as yet unsettled.

Harold Hibbert survived his retirement by only two years, and died of cancer of the pancreas in a Philadelphia hospital on May 13, 1945, after a lingering illness. His personal library, comprising some 1,500 volumes, has been kept intact and as the Hibbert Library is housed in the research laboratory of the Crown Zellerbach Corporation of Camas, Washington. He is survived by his widow, currently resident in New Haven, Connecticut. They had no children. He is memorialized at McGill University by the Harold Hibbert Memorial Fellowship, established by his younger brother Ernest (1879–1948) with an endowment of $100,000. This brother, a British-trained mining engineer, had been concerned with the technical development of the great Noranda gold and copper strike in the wilds of northwestern Quebec. The youngest brother Arthur (1883–1947) was likewise a mining engineer of high repute, who distinguished himself in the British Corps of Engineers in the First World War. The eldest brother Frank (1875—) is still engaged in manufacture in London. Harold is further memorialized by the two "Harold Hibbert Memorial Prizes" awarded annually in the Chemistry Department of the University of Manchester for the two best theses presented during the previous year.

Harold Hibbert was the recipient of the LL. D. degree *honoris causa* from the University of British Columbia in 1936; he became an Honorary Member of the Society of Chemical Industry (London) in 1943 and was elected to the National Academy of Sciences (U. S. A.) in 1945. He was a Fellow of the Royal Society of Canada. He served on the editorial board of *Cellulosechemie*. In addition, he was a member or fellow of the following societies: American Association for the Advancement of Science; American Chemical Society (Chairman, New Haven Section, 1920, and Division of Cellulose Chemistry, 1920–1922); American Pulp and Paper Association; Canadian Chemical Association; Canadian Pulp and Paper Association; Deutsche chemische Gesellschaft; Royal Institute of Chemistry (London); Sigma Xi; Society of Chemical Industry (Chairman, Montreal Section, 1930); Technical Association of the Pulp and Paper Industry; and Textile Institute (England).

Hibbert's was a colorful and vivid personality. He was a tall and strikingly handsome man. He was high-spirited, always optimistic, and a hard worker. His skill in debate and critique will ever be remembered by those who attended with him the meetings of the American Chemical Society. He was a true scholar and had read widely in many fields for pleasure, profit, and relaxation. His excellent background in English literature enabled him to write and to speak with clarity and forcefulness. He loved to recite from memory the verses of the great English poets. He was the possessor of a fine baritone voice and enjoyed singing airs from *The Messiah* or the rollicking songs of old England. He loved the great outdoors and, with Mrs. Hibbert, was an enthusiastic watcher of bird life. A vivid personality is gone, but his scientific attainments will long survive in his publications and in the students he so markedly inspired.

For valued assistance in preparing this memoir I am indebted to many of the former associates of Professor Hibbert, and especially to Mrs. Harold Hibbert, Dr. E. V. White, Professor C. B. Purves, and Mr. J. D. Crum.

KEY TO ABBREVIATIONS

Am. Dyestuff Reptr. = American Dyestuff Reporter
Ann. = Justus Liebigs Annalen der Chemie
Arch. Biochem. = Archives of Biochemistry
Ber. = Berichte der deutschen chemischen Gesellschaft
Can. J. Research = Canadian Journal of Research
Chem. & Met. Eng. = Chemical and Metallurgical Engineering
Ind. Eng. Chem. = Industrial and Engineering Chemistry
Ind. Eng. Chem. Anal. Ed. = Industrial and Engineering Chemistry, Analytical Edition
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Chem. Soc. = Journal of the Chemical Society (London)
J. Ind. Eng. Chem. = The Journal of Industrial and Engineering Chemistry
J. Soc. Chem. Ind. (London) = Journal of the Society of Chemical Industry (London)
Paper Trade J. = Paper Trade Journal
Proc. Chem. Soc. = Proceedings of the Chemical Society (London)
Pulp Paper Can. = Pulp and Paper of Canada
Pulp Paper Mag. Can. = Pulp and Paper Magazine of Canada
Z. ges. Schiess- u. Sprengstoffw. = Zeitschrift für das gesamte Schiess- und Sprengstoffwesen

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Claude Silbert Hudson

CLAUDE SILBERT HUDSON

January 26, 1881—December 27, 1952

BY LYNDON F. SMALL AND MELVILLE L. WOLFROM

WITH THE PASSING of Claude S. Hudson, American chemistry lost one of its ablest representatives, one whose brilliant researches had a predominant influence in the modern carbohydrate field for over forty years. Seldom is there found in a devoted scientist such a combination of friendly personality, keen wit, and complete disregard for restricting conventions. His long and delightful stories, both proper and ribald, will long be remembered by those privileged to have heard them. Although of modest and unassuming manner, Hudson took great pride in the perfection of his work, and in the honors which he received, and showed an almost naive pleasure in the ceremonies connected with his numerous awards. In view of Hudson's reticence concerning his personal history, it is fortunate that H. O. L. Fischer was able to induce him to furnish a record of his life in connection with the publication of his collected papers in 1946.

Claude S. Hudson, the second child of William James and Maude Celestia (Wilson) Hudson, was born January 26, 1881, in Atlanta, Georgia. His father's ancestry was Scottish, that of his mother a mixture of English, Scots, and Huguenot French. Shortly after the War between the States, William Hudson moved from his early home in South Carolina to Georgia and, when Claude was about three years old, took his family to Mobile, Alabama.

In this small southern city at the head of Mobile Bay, Claude and his older brother William spent their youth close to nature in an atmosphere of peace and plenty. Hudson writes with nostalgia of the long southern summers and mild winters, with the opportunities for swimming, fishing, and boating. It seems probable that Hudson's later love of nature and its manifestations was deeply rooted in this boyhood, though one might often suspect that his unusual knowledge of botany was acquired because of a surmise that this or that species of plant might contain some new sugar.

At high-school age he entered the University Military School for college preparation, and came under the influence of Julius T. Wright, an ideal type of educator and character builder. The secretary of the Mobile Y. M. C. A., the Rev. A. C. Harte, was also a close friend, whose culture and charm left a deep impression.

With a strong religious background and a great interest in church activities, Hudson decided to study for the Presbyterian ministery, and chose Princeton University for his preparation. There he enrolled for the B. Sc. degree in 1897 and, as he himself states, a more naive and gullible freshman never entered the University. He was a friendless soul in a land of strange customs and stranger speech, speaking a dialect that his classmates found equally strange.

In this freshman year he fought homesickness by strict devotion to his prescribed studies, and in particular became so interested in the inspiring chemical lectures and demonstrations of Professor L. W. McCay that he decided in all sincerity that the best way to train for the ministry would be to acquire all the science possible. Perhaps at this point a good minister was lost, for Hudson later had a striking ability to make any topic whatsover interesting to his listeners.

After a summer helping his friend Mr. Harte in his duties as chaplain of the Second Alabama Regiment (Spanish-American War), he returned with new vigor to his scientific program, with a feeling that he had no talent for Christian work. During the ensuing three years he became so fascinated by his studies in chemistry, physics, astronomy, geology, and mathematics under a distinguished group of teachers that the idea of the ministry was completely abandoned in favor of a scientific career.

Shortly before his graduation from Princeton in 1901, Hudson began to realize that the prospects for a future in science were indeed scanty for an unknown young bachelor of science coming out into a world where he had no influential connections, and he applied to his old friend Mr. Wright for an instructorship at the University Military School in Mobile. Scarcely had he been accepted in this capacity, when he was offered appointment to the Princeton Class of 1860 Fellowship in Experimental Science. His release from the Mobile obligation was easily arranged, and in the fall of 1901 he entered upon the duties of the Fellowship.

Hudson's interest at that time was primarily in physical chemistry, a phase that was totally neglected by the Chemistry Department, and he therefore chose to work in the Physics Department, in collaboration with Professors E. H. Loomis and William F. Magie. This was a critical decision, both for Hudson and for carbohydrate chemistry. It was here, during the purification of a sample of milk sugar, that Hudson observed the already known but unexplained phenomenon of mutarotation. His curiosity aroused, Hudson begged permission to explore this, and conducted an investigation of the forms of milk sugar which did not explain mutarotation, but committed him to sugar chemistry, and resulted in his first publication, in the *Princeton University Bulletin*. In June, 1902, he was awarded the Master of Science degree.

Hudson's parents were eager to have him continue his studies abroad, and believed that with the strictest economy they might be able to support such a program for three years. On the advice of Professor Loomis it was decided that Hudson should go to Nernst's institute at Göttingen. In Nernst's laboratory he continued his work on the mutarotation of lactose, and in return he and an American colleague taught Nernst to play poker, as preparation for an impending trip of Nernst to America. They did not, however, succeed in convincing the worthy professor of the danger of being scalped by the Indians around New York.

In the spring of 1903, Hudson learned that his father's financial situation had become unfavorable, and that his stay in Europe must be limited to one year; he and Nernst then agreed that it would be advantageous for him to spend his second semester with Van't Hoff in Berlin. Before leaving Göttingen, Hudson was able to visit for a short time in the laboratory of Gustav Tammann, where he demonstrated the closed-ring solubility curve of the nicotine-water system. This resulted in one of the few publications made by Hudson which were not concerned with some aspect of carbohydrate chemistry.

While in Berlin, Hudson had the opportunity to meet Emil Fischer, at the International Chemical Congress, although he did not realize at the time what a profound influence Fischer's work would have on his later activities. Here also he became acquainted with Professor A. A. Noyes, and was successful in obtaining a research assistantship in the new Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology.

At Boston he was able to continue some of his work on milk sugar, but his proposal to extend his studies to mannose had to be denied because of lack of funds. With the aid of Professor Magie, Hudson returned to Princeton as an instructor in physics (1904–1905). This was followed by two years in a similar capacity at the University of Illinois. In 1906 Hudson had married Alice Abbott, of Urbana, and even in those times was having difficulty in getting along on a salary of $900 a year. Moreover, he was now certain that his inclination and ability were far more toward chemistry than physics. In desperation, he was on the point of abandoning a scientific career and entering his father's phosphate mining business, when he received an offer from his former Göttingen colleague, John Clement, to join the U. S. Geological Survey as a physicist. In the transition, Hudson stopped at Princeton long enough to take his final examination for the Ph. D. degree, *magna cum laude* (1907). The government position was of short duration because of reduction in force. There followed a brief interval of industrial employment in physical and chemical testing of asphaltic substances at Perth Amboy, N. J.

In 1908, Hudson secured an appointment in Washington, as a routine analyst in Harvey W. Wiley's "poison squad," investigating adulteration of foods. This work Hudson was able to so systematize that, with the cooperation of a sympathetic supervisor, he could devote considerable time to studies of the hydrolysis of sucrose by invertase. Dr. Wiley himself became interested in this work and provided an assistant, and C. S. Hudson was really launched on his carbohydrate career.

In 1911–1912, Hudson took leave of absence to serve as Acting Professor of Physical Chemistry at Princeton, substituting for Professor G. A. Hulett. This was a most unusual course in physical chemistry. Hudson lectured for some weeks on subject matter with which he was familiar, then, having reached the bottom of the barrel, announced that the class did not know enough German ever to get anywhere, and for the remainder of the term taught chemical German.

Hudson's year at Princeton was by no means a loss, for he assembled a group of enthusiastic co-workers, some of whom followed him on his return to the Bureau of Chemistry, where in 1912 Dr. Carl L. Alsberg, successor to Dr. Wiley, established the Carbohydrate Laboratory. Hudson's recondite researches were supported to the utmost by Dr. Alsberg, as they were later in the Public Health Service, even though they had little direct bearing on the enforcement of the pure food laws or the health of the nation.

With the advent of war in 1917, Hudson was loaned to the War Department for crucial experiments on activated carbon for gas masks, and for four years after the war he acted as a consulting chemist on decolorizing carbon, yeast, and brewing problems. Beer was a subject of great personal interest to him, and during the prohibition era he maintained a special refrigerator set to the optimum temperature to produce a sound brew (at least in comparison with most beer of this period).

In 1923 Hudson was called to the National Bureau of Standards by Frederick J. Bates, Chief of the Polarimetry Section, to carry out research studies on sugars, an opportunity which he accepted with delight. With the exception of a year spent in the Hawaiian Islands consulting on problems of the pineapple canning industry, this fruitful research period extended until 1928. Hudson attracted many brilliant young scientists whose names and discoveries were later to become well known in carbohydrate chemistry. He always worked with his own hands as well as with his brain, and transmitted his patience and extraordinary skill to his collaborators. It is said that in spite of his care in handling rare sugars, he once upset a small beaker of viscous sirup in the center of his office desk. Perhaps as an object lesson, he wrote and worked for months around this sticky mess, until it finally crystallized and could be removed without loss.

The high reputation which Hudson had acquired from his researches at the Bureau of Standards had an unexpected result. In 1928 he received an invitation from Dr. G. W. McCoy, Director of the Hygienic Laboratory, to serve as Professor of Chemistry in the U. S. Public Health Service, a position which had recently been vacated by Professor William Mansfield Clark. Hudson had a difficult decision to make, for the Hygienic Laboratory was primarily a medical institute dealing with practical problems of public health. One might easily question whether such an organization would long support fundamental studies in sugar chemistry. There was precedent, however, in P. A. Levene's basic researches on carbohydrates at the Rockefeller Institute for Medical Research and, at the Hygienic Laboratory itself, in the outstanding contributions of Clark on oxidation-reduction systems. The chemistry of carbohydrates, moreover, is closely connected with human nutrition. Hudson accepted the offer of Dr. McCoy, a decision that he never had occasion to regret.

During his last months at the Bureau of Standards, Hudson had succeeded in preparing several kilograms of the rare trisaccharide melezitose from "gritty honey," and with the collusion of several associates he quietly took this along when he moved. This caused considerable trauma, which ultimately healed.

Early in 1929 Hudson was firmly established with twelve coworkers at the Hygienic Laboratory (later National Institutes of

Health), and here began the most productive and happy years of his career. With the small load of administrative work that was involved, he was able to devote his time almost entirely to his beloved sugars and enzymes. The practical problems of chemistry in public health which came along he turned over to his long-time associates, Dr. Elias Elvove and Mr. C. G. Remsburg.

It was in this period, from 1928 until his retirement in 1951, that the major portion of Hudson's brilliant researches was accomplished, in association with Raymond M. Hann, Nelson K. Richtmyer, and Hewitt G. Fletcher, Jr., as well as many others whose names appear in the appended Bibliography. He exercised extraordinary care in the preparation, purification, and characterization of his products, and was equally meticulous in the publication of his results. He often said, "I don't like to report in the literature any experiment until I have been through it at least three times." He set similar standards for his co-workers, and was extremely intolerant of experimental failures resulting from poor technique or carelessness. Indeed it was frequently remarked of him, "Huddy is a wonderful friend, but a hard master to work for." In one instance, after many months of waiting, a co-worker obtained a seed-crystal of a rare sugar, and thus brought the whole product to crystallization. Without saving a crystal, his assistant brought the entire mass into solution for purification—and the whole waiting period had to be repeated. For days Hudson wandered around, muttering, "He threw away his bait, threw away his bait."

In his relationships with his fellow scientists, Hudson insisted upon the same rigid principles of precision and clarity that were exemplified in his own writings, but his criticism was often tempered with humor. An editor who became somewhat impatient for a review of a rather mediocre book on carbohydrate chemistry received the reply, "I have the book you refer to, and have placed it upon the shelf between the volumes of Emil Fischer's collected work, hoping that by the process of osmosis there may result something worth reviewing." To a colleague who had hitherto not published in the sugar field, and who wished an opinion on a manuscript, he wrote "Dear L.: I have read your paper carefully, and my first suggestion would be a change in the title. This should read 'Alice in Sugarland.' "

Hudson's fascinating anecdotes were occasionally built against a sugar background. A favorite whimsy was that two Hudsons dwelt in opposed mirrors from which they emerged at appropriate times. The L-Hudson was the convivial one who partook of intoxicating beverages, was strongly attracted by beautiful women, and was in general sinful. D-Hudson was the serious, sober, gentlemanly scientist. On the occasion of the Organic Symposium of the American Chemical Society at Richmond, L-Hudson was in charge. It became necessary for him to leave the auditorium, but alas, the only inconspicuous exit was a spiral staircase which was dextro-rotatory. With the help of friends he finally mounted this, but claimed for years that he had been racemized in the process.

In the later years of his life, although he was not in good health, Hudson's amazing productivity continued unabated. He regularly attended meetings of the American Chemical Society, although he usually left the presentation of papers to his younger co-workers. He was also active in the Starch Round Table, an annual meeting in some secluded place, of those interested in the chemistry of starch and other carbohydrates. In the time which he spared from scientific work, he took pleasure in ambling through the spring woods, or along the semitropical littoral at Kitty Hawk, North Carolina, identifying shrubs and woods plants, floating in the warm waters bordering the Gulf Stream, or speculating on the amounts of glucosamine that might be obtained from the waste of the crab meat canneries.

After retirement at the age of seventy in 1951, he still led a busy, though necessarily quiet, life. He maintained a small laboratory at the National Institutes of Health, but was chiefly occupied with writing manuscripts from accumulated data, and with editing a new volume of *Advances in Carbohydrate Chemistry*. During this period he also acted as consultant for a Midwest brewing firm. His activities were terminated by sudden death from a heart ailment on December 27, 1952.

Hudson was married four times, the first three of these marriages ending to his regret in divorce. His last marriage, in 1942, was to his childhood sweetheart, the then widowed Erin Gilmer Jones of Selma, Alabama. This last marriage was a happy one. By his first marriage he had three children: a son, William Abbott, and two daughters, Alice and Sally. His son William died in England in 1945 while serving in the U. S. Air Force. Hudson is survived by his daughters and his wife Erin.

Although most of Hudson's research was abstruse, its fundamental nature and importance were early recognized. It struck into the actual basis of life, nutrition, by way of starch, sugars, enzymes, fermentation, vitamins, and the energy cycle (ribose). He was elected to the National Academy of Sciences in 1927, to the Kaiserlich Leopoldinisch-Carolinisch Deutsche Akademie der Naturforscher (Halle) in 1932, and became an Honorary Fellow of the Chemical Society (London) in 1949. He was a charter member of the Academy of Medicine of Washington, D. C. (1936) and received the D. Sc. from Princeton University (1947). By the American Chemical Society, he was awarded the Nichols Medal of the New York Section (1916), the Willard Gibbs Medal of the Chicago Section (1929), the Hillebrand Prize of the Washington Section (1931), the Richards Medal of the Northeastern Section (1940), and the Borden Medal in 1941. The Franklin Institute of the State of Pennsylvania bestowed on him the Cresson Medal in 1942. The United States Government made him the first recipient of the Federal Security Agency Award, and industry honored him with the Grand Prize of the Sugar Research Foundation. After Hudson's death, the Division of Carbohydrate Chemistry of the American Chemical Society renamed its annual award "The Hudson Award" in memory of the first award of the Division, which was made to C. S. Hudson in 1946. He served as an associate editor of the *Journal of the American Chemical Society* and of the *Advances in Carbohydrate Chemistry*. He was chairman of the Organic Division of the American Chemical Society (1934) and served on several of the organic nomenclature committees of the Society.

The sixty-fifth birthday of Hudson was celebrated by a carbohydrate symposium and by the publication in book form of the 247 papers which had originated up to 1945 from his Laboratory. These two volumes may well take their place on the library shelf beside those of Emil Fischer's collected work, with which they may be considered isotonic. One of the principal banquet speakers on this occasion was Sir Norman Haworth, a loyal friend of Hudson in spite of their disagreement many years ago. In 1951, at his seventieth birthday, the time of his official retirement, Hudson's friends and colleagues again gathered in his honor at the National Naval Medical Center.

The carbohydrates constitute a group of carbon compounds that are essential to life and are concerned especially with energy transfers in animal and plant metabolism and in the chemical fixation of carbon dioxide under the influence of the radiant energy of the sun. Many chemists have made their contributions to the study of these substances, but Emil Fischer, Sir Norman Haworth, and Claude S. Hudson occupy prominent positions in the development of the structural chemistry of the carbohydrates. These men furnished inspirational leadership to many associates and trained investigators for the continuing work in this field. The great contribution of Emil Fischer was to establish the stereochemistry of the basic carbon chain in the *Bausteine* or monosaccharides of this group. Sir Norman Haworth utilized methylation techniques to determine the ring sizes of the monosaccharides and to fix the points of glycosidic union in the principal disaccharides and polysaccharides. Claude S. Hudson gave his main attention to the nature of the stereochemistry of the reducing or hemiacetal carbon of the sugars.

Hudson began his work by studying certain physicochemical aspects of sugar solutions, utilizing first the two known crystalline forms of the disaccharide lactose. It was shown that the mutarotation, in aqueous solution, of these anomeric forms, followed first order kinetics with the specific reaction constant being the same for either form. These studies were later extended, with like results, to the anomeric forms of D-glucose. Hudson then elaborated his theory of the maximum rate of solution whereby the rotation of an unknown anomer could be evaluated by measuring the solubility and polarimetric changes with time in a solution saturated with respect to the known anomer. The mutarotation of D-glucose in water was shown to be subject to general acid-base catalysis expressible in the equation

$$k = 0.0096 + 0.258[H^+] + 9750[OH^-].$$

This equation shows that the catalytic activity of hydroxyl ions is 40,000 times that of hydrogen ions and the first term of the equation allows the ionic dissociation of water to be evaluated as 1.0×10^{-14} at 25°. Continued interest in the solid phases of sugars led to the establishment of molecular compounds between them and to interesting studies on the anomeric nature of sugar racemates. The sugars form molecular compounds with halides and a number of these were characterized as to anomeric form; an unstable hydrogen chloride addition compound of methyl α-D-fructofuranoside was encountered.

In the course of these studies, concerned essentially with the physicochemical properties of sugar solutions, it was necessary to prepare numerous sugars in a high state of purity. Thus arose the many publications concerned with the preparation of sugars from their natural sources. Sugar chemists know that these preparative directions of Hudson are exact and unfailing, and they have been of inestimable value. Strangely, Hudson received some criticism of these publications and even had a few refused by editors on the grounds that the directions, which indeed made the difference between crystals at the finish or no crystals, were of insufficient novelty. His last publication along these lines appeared in 1951 and was entitled

"Improvements in the Preparation of L-Arabinose from Mesquite Gum."

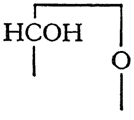
Hudson was always a lone worker and was a member of no school. His early training in physics gave him an exactitude in measurement and thought, while his association with the great and imaginative Van't Hoff, though short, exerted a profound impression upon him. Van't Hoff had published some speculations on "optical superposition" or the possible additive nature of optical rotatory power. More data were required, and Hudson recognized that in the carbohydrates there was at hand the largest known group of optically active isomers of known configuration which would be ideal for the further exploration of these effects. In his lactone rule formulation he noted that the optical rotatory sign of an aldonic acid lactone, of significant rotation, was controlled by the configuration of the carbon bearing the hydroxyl group involved in the ring closure. The rotatory sign of the amides, phenylhydrazides, and benzimidazoles of the aldonic acids was shown to be conditioned by the configuration of the center adjacent to the carboxyl function.

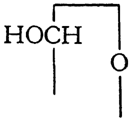
That part of the study of the relation between structure and rotatory power which occupied Hudson for the greater part of his life was concerned with the contribution made by the anomeric carbon center of the sugars. It was elaborated in his rules of isorotation, which state that if the rotation is divided into that (A) contributed by the anomeric center and that (B) of the remaining centers, then, in any anomeric pair, the sum of their molecular rotations is a constant characteristic of the B portion and the difference is a constant characteristic of the A part.

$$\text{For the } \alpha\text{–}\mathrm{D} \text{ anomer, } A+B=[M]$$

$$\text{For the } \beta\text{–}\mathrm{D} \text{ anomer, } -A+B=[M]$$

When Hudson began this work, anomeric forms had frequently not been well separated and a state of confusion existed in their nomenclature. He brought order in with his rule, originally empirical, that the more dextrorotatory (D series) member of an anomeric pair was to be designated *α* and its hydroxyl, or substituted hydroxyl, was to be written to the right in the Fischer projection formula.

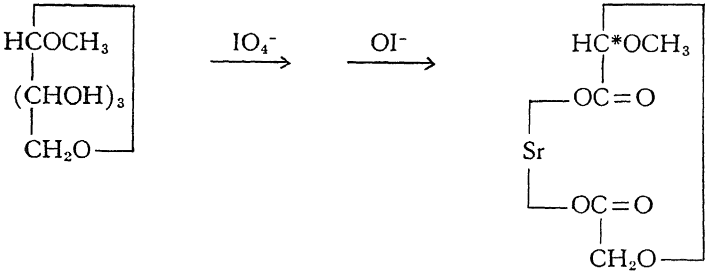

α-D


β-D

These modified rules of optical superposition were found to have limitations because the effects were partly constitutive and not strictly colligative. Nevertheless, they hold remarkably well in closely related structures and are infallible for making anomeric assignments.

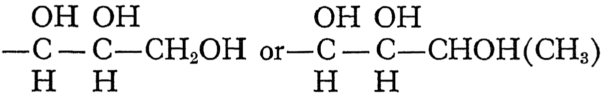
Hudson found in the acetates of the sugars a fruitful source of readily prepared and easily purified anomers. When the acetates failed to yield good derivatives, as in the pentose series, the benzoates proved useful. A handicap to the sugar chemist is the unavailability of many of the fundamental hexose structures. Hudson overcame this by finding most of these structures available in the higher sugars. Thus, while D-gulose is a sirup and difficulty preparable, the "*α–d*-glucoheptose" (D-*glycero*-D-*gulo*-heptose) of Emil Fischer is a readily crystallizable and available sugar which bears the D-gulose structure in its aldose-functioning portion. The first evidence, on a crystalline basis, for a second ring form in a sugar was provided in 1916 by the characterization of the four isomeric pentaacetates, in two anomeric pairs, of D-galactose.

Application of the *α*–glycol-splitting metaperiodate ion oxidant to the sugar glycosides resulted in a confirmation of their ring size, established first in other laboratories by methylation techniques, and a configurational correlation between anomers of different sugar structures. Thus, it was found that all of the more dextrorotatory anomeric methyl D-pentopyranosides did indeed have the same order of groups about the anomeric carbon. It had been considered that the arabinose structure might provide an exception to the Hudson anomeric nomenclature rules, but this was found to be not the case. The anomeric configurations and ring structures of the unsubstituted sugars are difficult to ascertain by direct methods but insight into this problem was obtained by the initiation of kinetic studies on the oxidation of aldoses with hypobromite ion.



The mysteries of carbohydrate enzymic action always intrigued Hudson. His early studies on the hydrolysis of sucrose with invertase constitute one of the first proofs that enzymic reactions can follow the laws of mass action. He established that the action of invertase on sucrose was irreversible. He studied the rapid hydrolysis of sucrose with massive amounts of invertase (1908–1909) and demonstrated that the D-glucose component was liberated as α–D-glucopyranose and that the D-fructose component initially freed did not correspond to any known form of this sugar. It was later shown in other laboratories that D-fructose was combined in sucrose as the furanose ring form. The anomeric form of the D-fructofuranose component of sucrose was established as β by demonstrating that invertase hydrolyzed only β–D-fructofuranosides, a circumstance which allowed the α–D anomers to be isolated from their synthetic anomeric mixtures. Hudson carried out many studies on the purification of invertase but this problem is still unsolved.

Hudson always insisted on maintaining his carbohydrate research on a crystalline basis. He was therefore greatly pleased when J. B. Sumner prepared jack bean urease in crystalline form and showed that it was an intact protein. He remarked at the time that this formed an important milestone in the development of enzyme chemistry. He was likewise intrigued by the *Bacillus macerans* which produced crystalline cyclodextrins from starches. The enzyme responsible for this action was isolated in extract form and named *Bacillus macerans* amylase. The selective oxidizing action on alditols, undoubtedly enzymic, of the "mother of vinegar" organisms *Acetobacter xylinum* and *Acetobacter suboxydans,* was exploited for synthetic purposes and the latter organism was shown to require the terminal structure



$$-\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-CH_2OH \text{ or } -\overset{OH}{\underset{H}{C}}-\overset{OH}{\underset{H}{C}}-CHOH(CH_3)$$

for action.

Ketoses differ markedly in reactivity from the aldoses. Crystalline acetates of D-fructose were characterized and new fructosides were prepared. D-*altro*-Heptulose ("sedoheptose") was found in *Sedum spectabile* and now occupies a prominent position in the carbon fixation cycle of photosynthesis. D-*manno*-Heptulose and lactulose were synthesized by the action of dilute alkali upon the appropriate aldose. Turanose, one of the disaccharide scission products of the trisaccharide melezitose, was crystallized and shown, by very clever and unique experiments, to be 3–α-D-glucopyranosyl-D-fructose. As mentioned above, other ketoses were prepared by the action of *Acetobacter suboxydans* upon alditols.

In order to establish the configuration of the higher sugars, the preparation of their alditols was requisite and a number of these were characterized. A very comprehensive program on the establishment of the nature of the cyclic acetals of the pentitols and hexitols was carried through successfully and led to the formulation of rules on the relationship between the configuration of an alditol and the structures favored in its cyclic acetals. Reductive desulfurization was utilized to prove that natural polygalitol is 1,5-anhydro-D-glucitol and to confirm the structure of natural styracitol as 1,5-anhydro-D-mannitol. The reaction was extended to other sugars.

The formation of anhydro sugars by the pyrolysis of oligosaccharides and polysaccharides was explored. The *O*-isopropylidene derivatives were found to be useful in their isolation and purification. The main product, from the aldoses studied, was the 1,6-anhydro-β-D-glycopyranose, with an isomeric anhydride also being isolated in the D-galactose series; this was proved later, in another laboratory, to have the 1,6-anhydro-α-D-galactofuranose structure. "Sedoheptulosan," the nonreducing anhydride of "sedoheptose" that was early discovered to be formed in high yield by the action of hot dilute acid on the reducing sugar, was proved to have the 2,7-anhydro-β-D-*altro*-heptulopyranose structure and to be thus related to the 1,6-anhydro-β-D-aldohexopyranoses. D-Altrose, D-*ido*-heptulose, L-*gulo*-heptulose and D-*glycero*-D-*ido*-heptose formed similar anhydrides under acidic conditions. The formation of the 1,6-anhydro-β-D-aldopyranoses by the action of alkali on aryl β-D-aldopyranosides was elaborated. 1,6-Anhydro-2,3-*O*-isopropylidene-β-D-mannopyranose was utilized in the first syntheses of lactose, cellobiose and their 2-epimers.

Hudson early utilized the reaction by which a β-D acetate was converted to an α-D acetate (the reverse occurs in the arabinose structure) by zinc chloride in acetic anhydride. He later preferred sulfuric acid for this anomeric conversion. A striking result was obtained when it was established that aluminum chloride converted the octaacetates of lactose and cellobiose in chloroform solution, into hepta-*O*-acetyl-disaccharide chlorides in which the configuration of carbons two and three of the D-glucose moiety had been inverted.

The optical rotation of one of the pentaacetates of D-fructose did not conform to Hudson's isorotation rules and this was later shown, in another laboratory, to be an acyclic form designated *keto*-D-fructose pentaacetate. Other laboratories then proved that this was the usual occurrence in the direct acetylation of ketoses with acid catalysts at low temperatures. Two hexaacetates of the aldoheptose D-*glycero*-D-*galacto*-heptose, earlier designated *d*-α-mannoheptose, had been prepared in Hudson's laboratory in 1924 by hot acetylation of the aldose with sodium acetate and acetic anhydride. Ten years later one of these was proved to be D-*glycero*-*aldehydo*-D-*galacto*-heptose hexaacetate. Acyclic acetates were encountered in the acetolysis of methyl β-D-arabinopyranoside and in a series of unique reactions these were converted to the first known acyclic acetal in the sugar series, D-arabinose dimethyl acetal.

The greater stability toward acids of the benzoate over the acetate ester group allowed significant studies to be carried out on the reaction of the poly-*O*-benzoyl-aldosyl halides with alcohols.

Triphenylmethyl (trityl) chloride reacts preferentially with primary alcohols but it was shown that it could react also, under "forcing" conditions, with secondary alcohols.

The phenylosazones are greatly overrated for derivatizing sugars. A much better derivative, the phenylosotriazole, was discovered in Hudson's laboratory as an oxidation product of the phenylosazone with cupric ion. Fehling solution is an asymmetric alkaline copper oxidizing agent utilizing a cupric L-(*dextro*)-tartrate complex. Interesting changes were noted when the enantiomorphous D-(*levo*)-tartrate was employed.

Because of his emphasis upon crystalline products, polysaccharides did not interest Hudson a great deal. However, pioneering work was carried out on the periodate oxidation of cellulose and starch.

In the above brief recapitulation of the highlights in the work of the Hudson laboratory, no credit to co-workers or to other laboratories has been cited. The many co-workers' names are to be found in the Bibliography. The work of Claude S. Hudson and his associates will long stand as a monument of rigorous mathematical reasoning, exceptional clarity, and experimental cleverness.

We desire to thank Dr. Nelson K. Richtmyer, of the National Institutes of Health, Bethesda, Maryland, for valued assistance in preparing this memoir.

KEY TO ABBREVIATIONS

Am. Food J. = The American Food Journal
Bur. Standards J. Research = Bureau of Standards Journal of Research
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Biol. Chem. = The Journal of Biological Chemistry
J. Chem. Educ. = Journal of Chemical Education
J. Ind. Eng. Chem. = The Journal of Industrial and Engineering Chemistry
J. Org. Chem. = The Journal of Organic Chemistry
Phys. Rev. = The Physical Review
U. S. Dept. Agr., Bur. Chem. Circ. = United States Department of Agriculture, Bureau of Chemistry Circular
Z. physik. Chem. = Zeitschrift für physikalische Chemie

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Wendell M Latimer

WENDELL MITCHELL LATIMER

April 22, 1893—July 6, 1955

BY JOEL H. HILDEBRAND

AMONG THE PAPERS in the files of Wendell Mitchell Latimer, there was found an autobiographical account of his earlier years that is so interesting and so revealing of the influences that shaped his career that it is here reproduced *in toto:*

"I am the tenth generation from Robert Latimer, a retired sea captain, who settled at New London, Connecticut, about 1660. I am a member of the Society of Mayflower Descendants from the Reverend Brewster, whose granddaughter married a Latimer. My great-great-grandfather, Colonel Jonathan Latimer, commanded the Third Connecticut Volunteers at the Battle of Saratoga. After the war he and his seven sons migrated to Tennessee. My great-grandfather, Alexander Latimer went with the Rutledges from Tennessee to Illinois at the time of the founding of New Salem, Illinois. Soon after he introduced Abraham Lincoln to Ann Rutledge. Lincoln wrote a letter to my grandfather at the time of her death. Unfortunately this letter, a family treasure, was destroyed in the Chicago fire.

"My maternal grandmother, Nancy Cook, migrated from Nashua, New Hampshire, with her sister in the eighteen fifties to Lawrence, Kansas to 'save Kansas for the free states.' My maternal grandfather, Milton Mitchell, had gone to California by way of Panama from Ohio during the Gold Rush, 1849–1850. He returned overland in 1860 and met my grandmother on the trip home. He served in the

Ohio Artillery for the four years of the Civil War and rose to the rank of Captain. After the war, he and my grandmother were married and homesteaded in eastern Kansas. My mother was born there in a log cabin in 1867.

"My father was born in Knox County, Illinois, and went to Garnett, Kansas, to take over the management of a bank in that city about the year 1886. There he met and married my mother. I was born in Garnett on April 22, 1893. When I was three years of age, we moved to Kansas City where my father was engaged in the banking and brokerage business. We lived in the Quindaro District, and I attended Hawthorne Elementary School.

"My early years were extremely happy. I had a pony and cart of my own, and the family had several teams of horses and carriages for excursions about the city. In the summers we took many long trips. I recall those to New England, Northern Michigan, Colorado, and to the Buffalo, New York Exposition.

"When I was eight my father contracted typhoid fever and died. My mother was left with rather meager funds. She and I spent one winter with an uncle near Abingdon, Illinois, and then we went to live with my grandfather on a farm near Greely, Kansas. From ten to fifteen years, I lived the life of a typical farm boy. I attended school in Greely, but at the end of my first year of high school my mother decided that I should attend the Garnett High School, which was distinctly better. Since Garnett was some ten miles away, this meant that I took a room in Garnett and came home week ends.

"The principal of the Garnett High School was Mr. C. H. Oman, a man of high standards and of excellent administrative ability. He had a fine staff of teachers, and the quality of the instruction was superior to that given in most small schools. I was a member of the debating team and competed in the interclass track meets, but without much success in the latter.

"In 1911 I entered the University of Kansas. I worked on a good many odd jobs to help pay expenses and finally got the job of looking after the University Weather Bureau. The hours were bad, and three times a day I had to climb to the top of the highest building for wind velocity measurements. It was, nevertheless, one of the prized jobs of the university and included attending the university seismograph.

"I entered the university with a pre-legal course in mind, and during the first two years was active in the debating clubs. However, I became disgusted with the methods which one had to use to win debates; logic counted for little as against the technique of building straw men and tearing them down with irony and sarcasm. I had taken considerable mathematics and since I had done well in these courses, I decided to change to a major in mathematics. In the summer session following my sophomore year, I had my first course in chemistry, and in my last two years I completed majors in both mathematics and chemistry.

"The summer of 1912 I spent in the Pacus Valley of New Mexico. I worked for a time in the melon fields, and then I signed up with a crew driving a bunch of steers from Artesia, New Mexico, up over the Caprock to Plainview, Texas. This was one of the last remaining bits of open range country, and my experiences with the cowboys on that trip have provided many rich memories. On the return trip I rode one hundred miles in a twenty-four hour interval.

"I received the A. B. degree in 1915 and remained at the Unversity of Kansas for two years as an assistant instructor in chemistry. In view of the fact that I had started my scientific studies so late, these additional years enabled me to build up a background in both chemistry and physics. I carried out a research program on the dielectric constant of ammonia up to its critical temperature. This work was under Professor H. P. Cady, an inspiring teacher with a truly great mind.

"In the summer of 1916 I attended the University of Chicago and took two courses with Professor Harkins. At this time Harkins was thinking a lot about the nucleus, and I found his lectures most stimulating.

"Professor G. N. Lewis offered me a fellowship at the University of California in 1917. I received the Ph. D. degree there in 1919, working under the direction of Professor G. E. Gibson. In 1918, when most of the staff were in France, I gave the freshman lectures. I probably should credit my debating experience for having been picked from the graduate student group to give these lectures.

"The years following the war were most exciting at Berkeley, and I was most happy to be asked to remain as a member of the staff. Dr. Gibson had translated Sackur's book on thermodynamics and probably had as clear a concept of entropy as anyone in the world. I owe much to him for my start in thermodynamics.

"I believe that I was the first to grasp the importance of the entropies of aqueous ions. These values have enabled us to use thermal data to calculate free energies and thus to give a thermodynamic treatment of most inorganic reactions. When I started this program, there was not a single ionic entropy known. With the assistance of an excellent group of graduate students over a period of thirty years, I have determined values for practically all of the stable inorganic aqueous ions. The theoretical interpretation of the ionic values has been significant in the general theory of strong electrolytes.

"One of the most useful applications of the large amount of data which I have accumulated on aqueous solutions was the preparation of extensive tables of oxidation-reduction potentials and of potential diagrams, relating the various oxidation states of every element. These potentials have had a profound influence upon the teaching of inorganic chemistry.

"In my early paper (1920) with W. H. Rodebush, I first clearly stated the principle of hydrogen bonding, which is now so generallly accepted. In this paper Rodebush wrote the first half on the general concept of polarization, and I wrote the last half which dealt with the structural interpretation. We naturally had to get G. N. Lewis' permission to publish the paper since we used his new theory of valence, and it was only with considerable argument that I was able to keep the hydrogen-bond theory in the paper.

"About 1934 I started W. F. Libby to work on some problems of soft Beta-emitters. As a graduate student, he developed many of the techniques which later were so important in his C^{14} work. After he received his degree, Libby and I started a seminar on nuclear problems which ran for many years. We attracted quite a group of young men, including Seaborg, Kennedy, Ruben, and Wahl. Thus in 1940, our department had one of the most active groups of nuclear chemists in the world, and this fact was of considerable significance in the A-bomb and general nuclear program."

This brief autobiography gives a glimpse of the influences and inherent characteristics that combined to produce the mature man and the scientist. Like the majority of successful scientists, he acknowledges his debt to a school whose principal was "a man of high standards," and whose "fine staff of teachers" provided superior instruction. Although his participation in debating in both school and college helped to make him the effective, clear lecturer and writer that he was, his intellectual integrity was such that he "became disgusted with the methods which one had to use to win debates." He became a biting critic of sophistry.

His contacts with many different sorts of people helped to make him an excellent judge of character. For many years he selected the teaching assistants and graduate students for the department of chemistry in Berkeley, and eventually, as chairman, he added to the regular staff many of the young men who are now maintaining its high standing in both teaching and research established originally by Gilbert N. Lewis.

He was unusually forthright. He left no one in doubt about his position. When he was a graduate student, presenting something or other in Colloquium, Gilbert Lewis constantly interrupted him, finally saying, "The trouble with you is that you don't take your audience into consideration." Wendell replied: "The trouble with me is that I can't keep my audience quiet long enough to say what I have to say." Lewis let him alone after that.

While in the Southwest Pacific during the war, addressing a group of chemical officers, at the same meeting to which a C. W. general had spoken, he said: "The General has just told you what is in the manuals. I will now tell you about recent developments that lead to very different conclusions." None but the thin-skinned could be offended by such remarks, because they would be accompanied by a disarming smile.

He was a shrewd card player. On one occasion, he and Roger Adams had been playing poker with two patent attorneys. After the game one of them said to Wendell: "I have to apologize to you. When we began I thought you were just another green pea."

He was an effective, stimulating teacher. He participated freely himself in the teaching of freshmen, both as lecturer and leader of quiz and laboratory sections. He worked first with Bray and eventually with Powell in the preparation and frequent revision of the laboratory manual, *A Course in General Chemistry*. The *Reference Book of Inorganic Chemistry,* by Latimer and Hildebrand was largely his work. Editions were published in 1929, 1940, and 1951.

Latimer served well both the Department of Chemistry and the University of California. He was an instructor from 1919 to 1921, an assistant professor from 1921 to 1924, and an associate professor from 1924 to 1931, when he became a professor. He was an assistant dean of the College of Letters and Science from 1923 to 1924, dean of the College of Chemistry from 1941 to 1949, and chairman of the department from 1945 to 1949. He participated freely in the affairs of the Academic Senate, serving at different times upon such important committees as Budget and Interdepartmental Relations, Educational Policy, and the elected Committee on Committees.

He started Willard F. Libby, who worked on his thesis under Latimer's direction, on the line of work that led ultimately to Libby's appointment to the United States Atomic Energy Commission. Together they organized a seminar on nuclear chemistry, whose participants included such future stars as Seaborg, Kennedy, and Wahl. His foresight in this matter laid one of the main foundations for the separation of plutonium and the trans-uranium elements, and the vast atomic energy program. From 1942 to 1946 he was director of a Manhattan (code name) Engineering District Contract on the chemistry of plutonium. He played a leading role in the chemistry program of the University of California's Radiation Laboratory throughout the period from the Second World War until his death. He was appointed in 1954 as a Consultant to the Atomic Energy Commission.

Latimer was one of the first to realize the disastrous consequences to this country if a potential enemy should first develop a thermonuclear (hydrogen) bomb. He was responsible for convincing many government officials of this fact and assisted in many ways the program which was started in 1950. Subsequent events fully confirmed his wisdom and foresight.

His war services to the nation were varied and notable. He was a member of and a Special Investigator for the National Defense Research Committee from 1941 to 1945. In 1943 he was a member of a War Department Mission to England. He was a technical observer and scientific expert at G.H.Q., South Pacific Area, in 1944.

After the war he was a member of the Chemical Corps Research Council from 1947 to 1951, of the Office of Naval Research Panel on Chemical Research from 1949 to 1950, and of the AEC Special Weapons Panel, from 1947 to 1950.

Over one hundred papers bear witness to both the quantity and the high quality of his scientific activity. The first, with W. H. Rodebush, referred to in his autobiography, although viewed at first with scepticism by Lewis, proved to be very important indeed. The special properties of the hydrogen bond set substances so bound far apart from those containing ordinary dipoles. It has recently become evident that hydrogen bonds are mainly responsible for the structure of genetic material. Pauling has said, "I believe that as the methods of structural chemistry are further applied to physiological problems it will be found that the significance of the hydrogen bond for physiology is greater than that of any other structural feature."

Most of his early investigations, begun under the inspiration of G. E. Gibson, had to do with heat capacity and entropy down to low temperatures. Soon after earning his doctorate he built the first successful hydrogen liquefier in the United States. W. F. Giauque has paid a warm tribute to Latimer's influence upon him. Lewis, Gibson, and Latimer published in 1922 a revision of the entropies of the elements.

His interest in entropy soon extended to the entropy of aqueous ions, an entirely new field, and the first paper (with R. M. Buffington) was followed by a number upon that subject. In 1936 he published a paper in *Chemical Reviews,* "The Entropy of Aqueous Ions and the Nature of the Entropy of Hydration." These studies, with his vast knowledge of inorganic reactions as a guide, led to a comprehensive correlation of thermal data, entropies, and electrode potentials, published in 1938 in the book, *The Oxidation States of the Elements and Their Potentials in Aqueous Solution.* A second edition appeared in 1952.

The value of Latimer's critical evaluations of oxidation potentials can hardly be overstated. They can be combined to predict the potentials of oxidation-reduction reactions for all the vast number of their combinations. They have taken their place as an essential part of the equipment of every competent inorganic chemist. They furnished valuable guides in working out the chemistry of the new trans-uranium elements, and were applied by Latimer in a paper, "Astrochemical Problems in the Formation of the Earth."

Scientific honors include membership in the National Academy of Sciences, and chairmanship of its Section of Chemistry from 1947 to 1950; the Distinguished Service Award from his alma mater, the University of Kansas, in 1948; the Presidential Certificate of Merit, in 1948; Faculty Research Lecture in 1953, an honor that the Academic Senate of the University of California annually bestows upon one of its members; the William H. Nichols Medal from the New York Section of the American Chemical Society, 1955, with a citation for his "Pioneer Studies on the Thermodynamics of Electrolytes, Especially the Entropies of Ions in Aqueous Solutions."

The Proceedings of the Seventh Meeting, in Lindau, in 1955, of the International Committee of Electrochemical Thermodynamics and Kinetics, published in 1957, carry a picture of Latimer as frontispiece and a full-page tribute to his memory, asserting that his "systematic work on oxidation states and potentials constitutes the very basis of this most important phase of C.I.T.C.E. activities." Concerning his death shortly before the meetings, it added: "This untimely death constitutes a severe loss for science and for the innumerable organizations and activities to which Professor Latimer contributed so much with such very great distinction."

Latimer spent the year 1930–1931 in Munich as a Guggenheim Fellow. From 1953 to 1955 he was a member of the Committee on Electrochemistry of the Internal Union of Pure and Applied Chemistry, and was appointed the same year to represent the National Academy of Sciences at the International Congress of Pure and Applied Chemistry in Zürich.

Latimer was editor of the Prentice-Hall chemistry series and served briefly as associate editor of the *Journal of Chemical Physics* and of *Chemical Reviews.*

Latimer lost his first wife, Bertha Eichenauer, whom he had married in 1917, also their son, Walter. In 1926 he married Glatha Hatfield. Their children are Eleanor Ann Colborn and Robert M., who is following in his father's footsteps. There are two grandchildren, Diane and Robert Edgar Colburn.

His health during later years was not good and he underwent several operations. He took it all stoically, hiding pain and discomfort under an ever-present sense of humor and interest in the welfare of students and colleagues. He died in his sleep July 6, 1955, at the age of sixty-two, at a time when he had been appointed to represent the National Academy of Sciences at the Fourteenth International Congress of Pure and Applied Chemistry in Zürich.

KEY TO ABBREVIATIONS

Chem. Eng. News = Chemical and Engineering News
Chem. Rev. = Chemical Reviews
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Chem. Ed. = Journal of Chemical Education
J. Chem. Phys. = Journal of Chemical Physics
J. Electrochem. Soc. = Journal of the Electrochemical Society
J. Phys. Chem. = Journal of Physical Chemistry
Phys. Rev. = Physical Review
Z. physik. Chem. = Zeitschrift für physikalische Chemie

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WILLIAM deBERNIERE MacNIDER

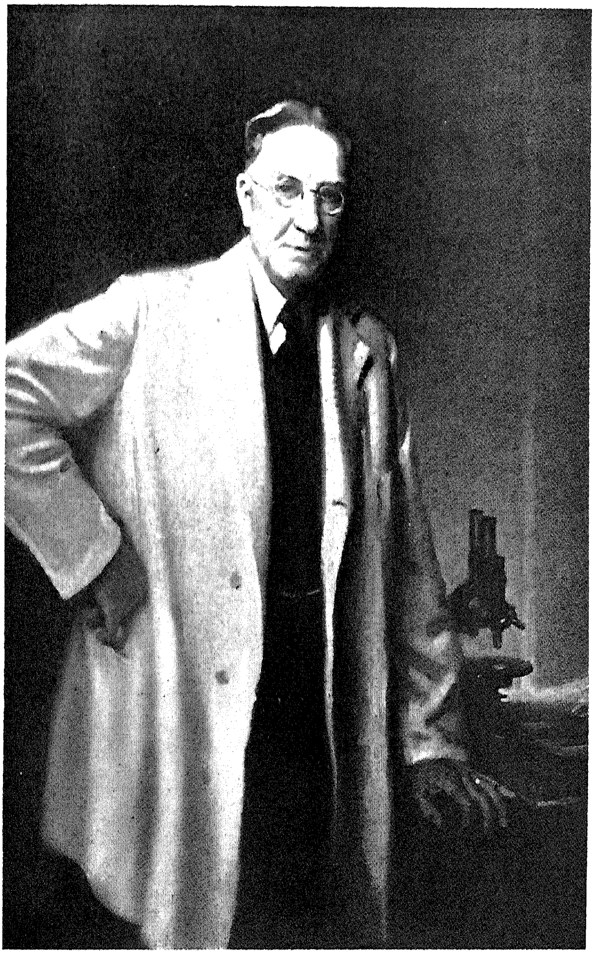
June 25, 1881—May 31, 1951

BY A. N. RICHARDS

WILLIAM deBERNIERE MACNIDER, son of Virginius St. Clair MacNider, M. D., and Sophia Beatty (Mallett) MacNider, was born in Chapel Hill, North Carolina, on June 25, 1881, in a house on West Franklin Street, a few hundred yards from the University to which the work of his adult life was devoted. He died in near-by Watts Hospital of Durham on May 31, 1951, from an acute development of a chronic respiratory disorder from which he had suffered intermittently for many years.

His father's ancestry has been traced back to the MacNair clan who, prior to about 1600, dwelt on the Isle of Skye. They emigrated to Ayrshire and intermarried with Clan MacAdair, with the result that the name successively became MacNadair, MacNader, and finally MacNider. John MacNider, ancestor of Virginius, joined Neal MacNeal's colony and came to the Cross Creek Section of North Carolina, near Fayetteville, in 1749.

His mother, Sophia Mallett, daughter of Dr. William P. Mallett, was descended from the Huguenot family of Malet of Rochelle, France of which Daniel Malet, "the original Mallett," was Governor General. Four of the Mallett brothers fled from France to England and from thence, in 1780, came to America. Two of them were the founders of the city of New Rochelle, N. Y.; a third remained near Charleston, S. C., their port of entry; the fourth came to Wilmington, N. C., thence to Fayetteville, where he founded the North Caro-



Wm deB. MacNider

lina branch of the family, of which William P. and his daughter, Sophia, were members.

Dr. William P. Mallett, born in Fayetteville, educated at Trinity College, Hartford, and the Medical College of South Carolina, practiced medicine in Chapel Hill from 1857 to 1889, the year of his death. His personal character and professional competence gave him a position of outstanding eminence as a citizen and as a general practitioner and consultant not only in Chapel Hill, but also in the surrounding county areas. In 1852 he performed one of the earliest Caesarean sections in this country; he served the University of North Carolina as physician to students and faculty and, although he died when his grandson, William, was only eight years old, his memory was one of the influences which directed the boy's mind toward the profession of medicine.

No evidence is available to indicate that as a boy, William showed a precocious bent toward science, but it is written that "he hunted in all the fields and woods, loved and cared for every wild flower; cultivated, enjoyed and shared every beautiful thing in the form of flower and shrub which can grow in Chapel Hill." That passion for natural beauty endured throughout his life. The chief formative influences of his early years were derived from the characters and devotion of his mother and her sister, "Aunt Eliza" Mallett, from his reverence for the tradition left by his grandfather Mallett, from associations with gifted members of the University faculty who were frequent guests in his mother's home, and from the experiences he enjoyed as a boy of thirteen or fourteen while accompanying his future teacher, Dr. Whitehead, on professional visits.

As an undergraduate in the College of the University, he got inspiration from the exceptionally able professor of biology, Henry V. P. Wilson, whom he served as student assistant during the school year 1899–1900. In MacNider's words, "Professor Wilson gave me rigorous instruction in zoology and under his guidance I saw for the first time the nephridium of the earthworm, perfect in its function and symmetrical beauty."

In 1899 MacNider enrolled as a student in the Medical School, then limited to two preclinical years in the laboratories at Chapel Hill. The Dean was the friend of his boyhood, Dr. Richard H. Whitehead, brought to Chapel Hill from the University of Virginia in 1890 to establish the North Carolina school, a man who attained great distinction not only from his success as an administrator, but also from his abilities as a scientist and physician. As professor of anatomy, he equipped a laboratory for research in histology and embryology; he also taught physiology and materia medica; he was physician to the University as well as to many families in the Chapel Hill area. His research interest in anatomy was broadened by summer work with Barker in Chicago and Mall in Baltimore. MacNider was appointed his assistant in anatomy from 1900 to 1902 and came to share his love of experimentation.

At the end of the academic year 1901–1902, MacNider had finished the work of three of the four years required for the M. D. degree and was contemplating a fourth and final year in another institution. It happened that in the spring of 1902 the decision was made by President F. P. Venable to bring to realization a plan inaugurated by Venable's predecessor, E. A. Alderman, which would add two years of clinical instruction to the existing preclinical years, and thus enable the University of North Carolina to award the degree of Doctor of Medicine. Hubert A. Royster, thirty-one years old, an able, ambitious, and courageous gynecological surgeon of Raleigh, N. C., was chosen to be dean, with the duties of designing the curriculum, choosing the clinical faculty, and managing the whole undertaking without expense to the mother University. Instruction was to be given in Raleigh. In addition to Royster, who took the chair of gynecology, the first major faculty consisted of four professors, all eminent practitioners in the Raleigh area, among them Royster's father, W. I. Royster, as Professor of Medicine. The doors of the clinical division opened in September, 1902. William deBerniere MacNider, the first applicant, was admitted to membership in the senior class; he was joined later by three others. Two applicants were admitted to the junior class, thus making a student body of six. MacNider received his M. D. degree in 1903, and for the two following years remained in Raleigh as Instructor in Medical Diagnosis. He lived at Dean Royster's home during those years and collaborated with him in the study of clinical problems in gynecology, from which two publications resulted, the titles of which head the Bibliography appended to this account. In 1910 the Raleigh project had to be abandoned, and the two-year course of the school was resumed.

In 1905 MacNider was recalled to Chapel Hill as Professor of Pharmacology. In those early years after graduation, he sought to amplify his training by spending summers in other medical centers. The first, in 1904, was in Baltimore in Osler's clinic at the Johns Hopkins Hospital. That experience left an indelible impression, memorialized in his essay, "The Way of a Teacher." Another summer was spent in Chicago, where he worked in physiology with S. A. Matthews and G. N. Stewart. Still another, 1908, was in Cleveland in the pharmacological laboratory of Torald Sollmann at the Western Reserve University Medical School.

The duties to which he was assigned upon his return from Raleigh to Chapel Hill were not restricted to pharmacology; he also taught or took part in the teaching of bacteriology, clinical diagnosis, and minor surgery; he shared in the responsibility for the medical care of students and faculty in the University Infirmary, a task which his grandfather, Mallett, and his teacher, Whitehead, had successively discharged years before him; he engaged in the practice of medicine in the community.

In 1918 he was one of the first five faculty members to receive the rank and title of Kenan Professor, bestowed as a recognition of "distinction in research, in teaching, or in service to the University." Among the others similarly honored were President Venable and MacNider's former teacher, Professor Wilson. In 1924 MacNider's title was changed to that of Kenan Research Professor; in 1937, while still retaining his professorship, he became Dean of the Medical

School and served in that capacity for three years. In 1950, he retired from active duty.

MacNider's work in Sollman's laboratory in Cleveland in 1908 constituted the beginning of his investigations of the structure and functions of the kidney, a subject which became a central research interest for the rest of his life. It is described in a preliminary publication in 1910 from the two laboratories, Western Reserve and North Carolina, followed by one in 1911 from the Chapel Hill laboratory. In it he aimed to study processes of regeneration in a necrotic area of the kidney, produced by ligation of a branch of the renal artery in dogs and cats. Most significant in relation to his future work was the finding that as blood vessels and connective tissue cells grew into the area new tubules were formed, the cells of which were flat and lacking in clearly defined boundaries.

At about the same time, influenced by the work of Schlayer in Germany and Pearce in the United States, in which were described the effects of a group of poisons on renal structure and function, he undertook to relate the effects of such poisons to urine formation and to the action of diuretics. Regarding the urine-forming mechanism of the kidney as made up of two systems, the blood vascular including the glomeruli, and the epithelial cells of the tubules, he hoped to find a poison which, by selective action, would disable one system, leaving the other intact and thus yield conditions for a conclusion as to which system is more largely responsible for urine formation and for effectiveness of diuretic drugs. As the previous workers had shown, cantharidin and arsenic exhibited predominantly vascular effects; chromates, mercury, and uranium acted predominantly upon the epithelium. MacNider found that urine continued to be formed and diuretics increased urine output, even when the vascular elements were the seat of congestion, provided only that the tubular epithelium was not seriously damaged; however, when the epithelium had become swollen, vacuolized, or necrotic, urine output decreased, even to the point of anuria, and diuretics failed to act. These latter effects he attributed to obstruction of the tubules by the swollen epithelium or by debris of necrotic cells. His conclusion, emphasized then and in later work, was that the functional capacity of the nephritic kidney depends more upon the integrity of the epithelium than upon the responsiveness of the vascular mechanism.

In the acute experiments with diuretics uranium was the toxic agent used. The principal effect of a small dose was the production of cloudy swelling of the epithelium of the distal segment of the proximal convoluted tubule; larger doses caused fatty degeneration, vacuolization, and necrosis, extending to the ascending limb of Henle's loop, where stainable lipoid accumulated. Glucose, albumin, casts, and acetone bodies appeared in the urine. By judicious selection of dose and time interval, the character and severity of the toxic effect could, to some extent at least, be predetermined. From this time (1913) on, uranium was one of the chief tools with which MacNider's renal explorations were made.

Further study of diuretics in uranium nephritis not only confirmed the conclusion stated above, but added other leads. These were: (1) that the severity of the changes which uranium produces in renal structures and urine composition is greater in adult than in young animals, and (2) that chloroform, used as an anesthetic to permit measurement of blood pressure and kidney volume, intensifies the severity of the uranium effects, and that its effect, too, is more pronounced in old than in young dogs.

Like others who had studied experimental nephritis, MacNider was impressed by the frequency with which the kidneys of seemingly normal dogs showed evidence of chronic nephritis, naturally acquired through unknown causes. Their urine contained albumin and casts; the kidneys, examined histologically, revealed a primary chronic glomerulo-nephritis. Pathological alteration of the tubules was relatively insignificant. Some tubules were found to be lined with flattened, atypical cells, evidence, it was assumed, of previous degeneration and repair.

Experiments carried out on these "naturally nephropathic" dogs, showed: (1) that the damaging effect of uranium was more intense and wide-spread than in normal dogs; (2) that the tubular regeneration which followed the acute effects of uranium was characterized by the production of flat cells, structurally less specialized than the normal cells which they replaced; and (3) that the cells of the regenerated epithelium, when subjected to a second poisoning with uranium, were less susceptible to its destructive effects than are normal cells. In these experiments, too, age was found to be a factor; the older the animal the more severe was the damage effected by uranium.

Early in his experiments with uranium, MacNider was impressed with the occurrence of glucose, acetone, and diacetic acid in the urine of poisoned animals. There was a rough parallelism between the excretion of these substances and the severity of the poisoning. The conclusion that acid intoxication is a factor in the degree of damage produced by uranium was strengthened by finding that intravenous sodium carbonate lessened not only the excretion of acetone bodies but also the severity of epithelial damage; it restored the capacity of the kidney to respond to diuretics.

In more detailed experiments, the acid intoxication from uranium was further defined by measuring the decrease in blood pH, alkali reserve, and alveolar CO_2 tension. The excretion of injected phenolsulfonephthalein (PSP) was diminished; urea and creatinine were retained in the blood. All of these effects were more pronounced in old than in young dogs. The disturbance in acid-base equilibrium was taken to represent a "tissue acidosis," ascribable to a general inhibition of oxidative enzymes and consequent depression of internal cell respirations. It was assumed that such enzymes are more abundant in the tissues of young animals, and that this was a possible reason for their greater resistance to the action of uranium.

The foregoing statements indicate the direction of MacNider's chief efforts during the first decade of his investigative career. They disclosed and partially clarified problems which were to occupy a large share of his future work and thought. He had focused upon uranium because of the selective and predictable characters of its action and because of the resemblance between the nephropathy produced by it and certain nephroses encountered in human pathology. His study of naturally acquired glomerulo-nephritis in dogs offered similar opportunities. The toxic actions of chloroform on the kidney presented problems of practical as well as scientific interest; so did the acidosis produced both by chloroform and uranium. Most important of all were the leads which he had opened on the factor of age in the severity of tissue poisonings and on the characters of tissue repair after injury.

In studies of the chronic effects of uranium, specifically directed at the factor of age, MacNider found that dogs less than one year old consistently survived the effects of dosages of uranium which were invariably fatal to dogs over six years of age. The old dogs excreted albumin, casts, and glucose in large amounts; urea and creatinine accumulated in the blood; PSP excretion diminished to zero; the alkali reserve of the blood was markedly reduced. Profound degeneration and necrosis of the tubular epithelium was found at autopsy.

Equivalent doses in the young dogs produced far less intense effects both upon blood and urine and upon renal structures. Swelling, edema, and necrotic changes were less severe, and as early as the tenth day extensive regenerative repair could be identified. The regenerated epithelial cells were flat and less specialized in structure than were the normal cells which they replaced. Urinary abnormalities, with the exception of decreased PSP excretion, disappeared. The acid-base equilibrium of the blood as indicated by the alkali reserve was restored to normal. After recovery the kidneys presented the picture of a permanent "chronic diffuse nephropathy."

In some of these experiments, the chronic effects of uranium were followed for as long as five years. Histological study of the kidneys of these animals revealed two different types of epithelial repair. In one type there was reconstruction of typically normal cuboidal cells, brought about by processes of mitosis from cells which had not undergone extensive destruction. In the other type, structural repair took place by an ingrowth of the flat cells, above referred to, relatively nonspecialized and imperfectly differentiated.

Studies were made to learn how these two types of regenerated epithelium would react to a second attack by uranium. In those animals which had survived a first poisoning and whose kidneys on biopsy showed restoration of epithelium of the normal type, the second poisoning produced even more severely destructive effects than did the first. They succumbed with all the symptoms, functional and pathological, produced by a larger dose given to a normal animal.

On the other hand, animals which had survived a first poisoning with the development of a chronic nephritis and replacement of normal tubular epithelium by flat, atypical cells, survived a second dose even larger than the first, with no degenerative changes in those atypical cells. It was apparent that a resistance to the toxic action of uranium had been acquired as a result of the substitution of atypical "embryonic" cells for the more specialized, more susceptible cells which had been destroyed by the first poisoning.

Concurrently with MacNider's studies of the pathology of renal damage inflicted by uranium or chloroform came his recognition of disturbances of general metabolism as indicated by the associated acidosis. He found that reduction in the alkali reserve of the blood might occur before morphological changes in renal structure could be identified. His conclusions in this connection are summarized at the end of a series of papers in the *Journal of Metabolic Research* (1926) as follows:

First, "The nephrotoxic action of uranium nitrate is in large measure due to its ability to induce and maintain a disturbance in the acid-base equilibrium of the blood which is furnished to the kidney, and in which blood chemical environment this organ must attempt to functionate in a normal manner. There is no reason to suppose that a similar statement does not apply to other organs equally important,"

Second, "In certain animals acutely nephropathic from uranium the use of sodium bicarbonate maintains the equilibrium of the blood. In such animals there is less evidence of renal injury and a more perfect maintenance of renal function," and

Third, "In other acutely nephropathic animals and in all animals with a naturally acquired glomerulo-nephropathy in which an acute injury has been superimposed on the chronic process, the use of sodium bicarbonate was unable to maintain this equilibrium. In such animals there was a marked disturbance in both the functional response of the kidney and in the degree to which the kidney was histologically preserved."

In these conclusions can be discerned the recognition of a general condition which he came to refer to as the "instability of the acid-base equilibrium of the blood"—a state in which, while measurement of the actual blood balance of acid-base may yield a normal figure for the alkali reserve, the total reserves of the body are inadequate to provide supplies of base necessary to compensate for excessive demands incident to excessive acid production or accumulation. The situations in which such instability is to be found were old age, advanced pregnancy, particularly in old animals, and chronic renal disease, either naturally acquired or resulting from an acute chemical or pathogenic insult from which partial recovery had occurred.

Although the chief focus of MacNider's investigative interest was the kidney, he was wholly aware that other physiological systems are involved in the complex of effects produced by the poisons which he studied. As early as 1919 he described the acute effects of uranium and mercury on the liver, and in 1932 he systematically undertook experiments on that organ, similar in design to those on the kidney. Uranium and chloroform were the agents used; excretion of phenoltetrachlorphthalein (TCP) served as a test of liver function; alkali reserve of blood indicated the state of the acid-base equilibrium;

morphological changes were followed by histological examinations of liver tissue, repeatedly taken at biopsies during the course of and again at the end of each of many experiments. The results were so like those obtained in studies of the kidney that they require only brief description.

A small dose of uranium (2 mg. per kilo) caused albuminous degeneration and edema of liver cells with little extensive necrosis. Excretion of TCP was delayed and alkali reserve reduced. Some four weeks later, cell structure had become normal, TCP excretion approached normal, and the alkali reserve was restored. When such a dog, after recovery, was given a second dose of uranium the effects were as severe as those which followed the initial dose.

When a larger initial dose of uranium was given (4 mg. per kilo) extensive necrosis of liver cells resulted, with greater decrease in alkali reserve and longer delay in TCP excretion. After four to six weeks the degenerated liver epithelium was found to have been replaced by flattened cells, less specialized in structure than the normal, which frequently formed syncytial cords of imperfectly differentiated cell substance.

Dogs which survived the larger dose, when again poisoned with uranium, resisted the second poisoning if the second dose of uranium was the same as the first. The atypical cells did not show injury; function as indicated by TCP was little affected. Tissue resistance had developed. However, if the second dose of uranium was sufficiently large, degenerative change in the atypical cells did occur. Their acquired resistance did not constitute an immunity.

Similar results yielding similar conclusions were obtained in experiments in which the second poisoning was produced by chloroform rather than uranium.

Finally, it was found that in some "senile" dogs, the "normal" liver epithelium was of the flat, syncytial type, and that these animals exhibited a resistance to uranium and chloroform similar to that exhibited by animals in which atypical epithelium had developed as a sequel to the acute injury.

In concluding a description of the above experiments MacNider remarks that in considering susceptibility or non-susceptibility to disease, especially those characterized by degenerative rather than inflammatory processes, the factor of changed morphology and changed power to resist must be recognized. Such shifts—metaplasias—in fixed cell types, as these experiments demonstrate, are examples of adaptation of animal tissues and organisms as a whole to an initially unfavorable physico-chemical environment; they may in part explain the survival of the fittest.

The foregoing account is limited to the major and what is believed to be the most important part of MacNider's investigative efforts. It is inadequate in that it fails to portray the passion for the discovery of new truth through experimentation which animated his life. "Research in any field is done primarily to find some new truth or part of a truth—regardless of immediate or practical application. . . . The finding of some small piece of truth is sufficient reward" (1920). "The desire to understand the unknown and the will to sacrifice to gain such information is the spiritual inwardness of University life" (1945).

It fails also to picture the enthusiasm which carried him through recurring discouragements in the course of his studies. Hundreds of experiments, requiring countless observations, analyses, and studies of tissue sections were conducted at the cost of unceasing labor and great personal expense; the camera lucida drawings and photomicrographs with which his papers are suberbly illustrated were secured largely at his own expense. At times he was desperate for funds needed to carry his dogs over a summer vacation. Once the Ella Sach Plotz Foundation came to his rescue; at other times he pledged his own property. Nights, Sundays, and vacation days were opportunities for research, as much as for relaxation and rest. Often a new observation would arouse excitement. In 1932, for example, a hastily written letter begins, "Did I tell you I had found a peach of a thing in the liver?" It goes on to describe the discovery of flattened, ribbonlike cords of liver cells, highly resistant to chloroform, in a dog, normal except for advanced age, and continues with the surmise that "the entire question of resistance and immunity can not be explained on a humoral basis, antibody formation or on the activity of wandering cells."

MacNider realized that the morphological changes which he identified must be the visible manifestations of chemical and physical complexities which were beyond the powers of his microscope and his chemical skill; thus deterred from their more intimate analysis, in his later years he devoted some of his energy to the development of broader biological generalizations. These reflected the influence of wide, serious, nontechnical reading, and especially of the philosophical writings of two scientists whom he revered, L. J. Henderson and J. S. Haldane. This phase of his mind is shown in the titles of papers published during the last decade of his life such as "Adjustability of the Life Process to Injurious Agents" and "Age, Change and the Adapted Life." This account would be incomplete if these themes were not represented in it.

Concerning adaptation: "Fixity of any order, even fixity of purpose, tends to bind and render inelastic the structure or the individual in which such a property develops. It is a quality which is inimical to adaptation, and tissues or organisms without this quality of elasticity, of variability, have difficulty in meeting the exigencies of life which is made up of periods of adequate adaptation which may be of such a specialized nature as to produce the symptoms and later show the signs of disease.

"In thinking of the adjusted normal animal organism and the changes it can withstand one must conclude with a certain degree of assurance that the life span of such an individual was intended to be much longer than we now make it.

"Such natural factors of safety have not been appreciated by us as reserves. Through excess we have foolishly drawn upon them in their abundance for our normal way of life and depleted these factors of safety. Over-exercise, over-eating, over-worrying, more rarely over-drinking diminish these factors of endowed and natural safety, this abundant reserve tissue, and prepare us for the advent of tissues so different from the reserve that we designate them pathological. However, even tissues of this order may safeguard us against ourselves by furnishing us an excess of tissue which, although altered, not only functions and in part adjusts us, but at the same time endows us with a factor of resistance against further injury.

"Even in those states of tissue change which are designated disease there is evidence that we may become readjusted to them at certain modified levels of physiological effectiveness. There is an inherent urge on the part of cells, not for death, but for life. The changes of degeneration which many such units can withstand and their capacity of recuperation and repair, if given an opportunity, constitute, as a composite, one of the major manifestations of life.

"These changes in cell form as life adjusts and adapts itself to a variety of chemical experiences are impressive as they give to one a conception of the elasticity and adjustability of such changes, ever tending to adapt an organ in which they occur and the organism, the individual as a whole, to life at some level of effectiveness. The observations lead one away from a concept of the fixity, the static nature and inelasticity of life processes, even when expressed as chemical equations within cells, as a form of life. It would appear that change is the essence of life and that an organ or organism, with the greater degree of adaptability to changed conditions is in turn the more likely to survive.

"Finally and in summary, when we contemplate our varied factors for safety, for a continuation of life as an everchanging, shifting, yet balanced living entity, we may wonder at the brief duration of our life span. The duality of certain organs and the superabundance of reserve tissue in those not so paired, the ability of tissues automatically to throw into operation functional defense mechanisms, degenerative changes in tissues leading to processes of repair which afford tissue resistance, all tend to hold us not only in life, but in a balanced and, in some measure, an effective life."

It will have been noted that even in the very early stages of MacNider's studies of the reactions of tissues to poisons he clearly recognized the influence of age on the intensity and quality of effect; as more and more evidence accumulated, he insisted with increasing emphasis upon the importance of the study of the aging process. It was natural, therefore, that he should have been one of those who, more than twenty years ago, advocated and worked for the development of gerontology and geriatrics as discrete divisions of human biology and medicine. His mature belief is indicated in the following quotation:

"Many are interested in embryonic life; the life of infancy and childhood; the changing life and puberty; but few are interested in the changing life of the middle aged as it advances into senility and finally to a senile and perhaps physiological death.

"Understanding the physical and chemical changes associated with the aging process is more important and more difficult than that of changes in infancy and childhood. In the latter the life urge is toward survival; in the former the tendency is the reverse.

"Infancy and youth, the aged, and the senile represent chemical equations in progressive adventure from life into death. The usual concept of age is that of a fixed, natural and irreversible process, chronologically determined by the species of animal, which within certain fairly constant limitations terminates in death. Age and the processes constituting it should be seen and appreciated as living, fluid, elastic states of give-and-take for the sake of adjustment as an organism passes through its life span with those changes indicative of aging being in some measure manifestatious of an attempt of such an organism, man, to effect a working adaptation to these years. Certain of these signs of aging represent failures in such an attempt. The important consideration for the student of aging is to ascertain the reasons for such failure and the cause for those states of premature aging and instability which unrelate the individual to that environment in which he has to live and maintain functional adjustment.

"The aging process is not one which proceeds from a certain peak of perfection uninterruptedly downward. Its course is characterized by variations in cell susceptibility and transitory states of cell resistance which give an irregular curve of downward progress—points of depression, increased susceptibility; points of elevation, variable in duration at which resistance is increased. As aging progresses such transitory states of cell adaptation to it become less and less effective, finally manifesting their inability in terms of such depressed function or lack of function on the part of an organ system that the life of the organism as a whole comes to an end."

It is appropriate now to attempt to identify and estimate the influence which MacNider's work, ideals, and personality exerted upon the progress of medicine, upon the University in which he worked for more than half a century, and upon the individuals with whom he lived.

His part in the early stages of development of gerontology and geriatrics in this country—disciplines which now have their own national societies and journals—was an outcome of his long insistance on the part played by age in the reactions of tissues of laboratory animals to poisons and upon age alone as a factor in tissue change. In 1937 he was an active participant in a conference of some twenty scientists called to discuss material on aging which was to be assembled in a book planned by E. V. Cowdry and published in 1939 under the title *Problems of Ageing.* That conference was the first of a long series, sponsored and supported by the Josiah Macy Jr. Foundation, which gave strong impetus to the advancement of knowledge of that field. For six consecutive years, 1940 to 1946, MacNider was chairman of those conferences, and the group, under his chairmanship, has been credited with having played the leading role in the development of the field of aging in this country. When the Gerontological Society was founded, MacNider was its first president. He was a member of the National Research Council's Committee on Aging and became consultant on aging to the National Institutes of Health.

Similarly specific examples of leadership in the broader, more general areas of medicine are less easy to define, but there are many impressive evidences available which prove the extent and value of his influence. In the south particularly, he came to be regarded as the regional personification of the relationship between experimental science and medical advance—witness his presidencies of the North Carolina State Medical Society (1925–26) and the Elisha Mitchell Scientific Society, his honorary degrees from the Medical College of Virginia (1933) and from Davidson College (1934), and the many invitations he received to address southern medical organizations. A member of the Association of American Physicians, in 1941 he received its highly prized Kober Medal. He received and accepted one of the annual invitations given by the Medical Staff of the Peter Bent Brigham Hospital to come to Boston and for a month to assume the duties of Physician-in-Chief in that hospital—an extraordinary tribute to be given to a laboratory man. Another distinction, similarly unusual, was the selection of Dr. MacNider to deliver the Convocation Address at the twenty-second annual session of the American College of Physicians in 1942. For many years he served as a member of the National Board of Medical Examiners; in 1927 he was chairman of the Section of Pharmacology and Therapeutics of the American Medical Association; for two years, 1932 to 1934, he was the elected president of the American Society of Pharmacology and Experimental Therapeutics, and in 1941–42 was president of the Society for Experimental Biology and Medicine. The New York Academy of Medicine gave him the Gibbs Prize for the year 1930–31, and he received the Research Medal of the Southern Medical Association in 1933. Dr. MacNider was elected to the National Academy of Sciences in 1938.

His work on the effects of anaesthetics on acid-base equilibrium can be regarded as having had an influence in hastening recognition of the importance of protecting the electrolyte balance in relation to pre- and postoperative surgical care. He was a member of the research committee of the National Anaesthesia Research Society, and in 1934–35 was president of the International Research Society.

Neither an account of MacNider's laboratory investigations nor a listing of his services to medical organizations and of the honors bestowed on him represents, it is believed, the most important fruits of his character and activities—those which will be longest remembered and have the most lasting influence. These are more difficult to portray. They require familiarity with the spirit of the man, shown in devotion to his profession, to the University which he loved and served, to his students, to his neighbors, and to his friends, who were legion.

First of all, he was a physician, a true country doctor, whose readiness to care for the sick never lessened. It is as remarkable as it is unusual that one whose chief pursuits were in the laboratory and classroom should have so long continued to be on call for patients who wanted him. His earliest models were his grandfather, Mallett, and his teacher, Whitehead; later he was strongly influenced by the two Roysters, father and son, and, in a special degree, by Osler. Like them, he never regarded a patient as "a case," but always as a whole human being in need of all the help that another human being who happened to be a doctor could give.

He had little respect for a doctor who looked upon his profession as a means of personal enrichment, or for one who allowed social engagements or the financial status of a patient to influence his response to a need. One of his friends, disclaiming interest in what MacNider did in his laboratory, asked "How does he manage to get around to help so many folks who are sick or otherwise in trouble?"

He was a competent doctor. During the influenza epidemic of 1918, he was made responsible for the medical care of students and faculty in the infirmary. His associate, Dr. Coppridge, said he had never seen Dr. MacNider's peer in the art of diagnosis or in the mastery of scientific therapeutics.

He did not spare himself. One twenty-four-hour day can be cited. Called one evening to a farm two miles from town he found a woman, pregnant with twins, in a state of eclampsia. Helped by the husband and a Negro midwife who gave chloroform, he did a forceps delivery of the first child, breech presentation; he encountered no difficulty with the second. Treatment for shock was inaugurated with heat, coffee, and morphine. Back to the University for an 8:00 A.M. lecture in pharmacology. That finished, back to his patient, who was responding well to treatment. The midwife was feeding the babies with warm milk and corn bread crumbs! Then in the afternoon, a lecture in pathology. A final visit to the patient, and the day was over.

In considering MacNider's service to the University as a whole, it is interesting to recall that his fifty-one years of faculty membership lasted for slightly more than one third of the active existence of the University up to the year of his death, that period covered the full terms of office of four presidents and the beginning year of a fifth. The University and the town of Chapel Hill were founded at the same time, 1795. The University had its most vigorous growth from a college to a university during the years 1900 to 1930, and the population of the town grew in those years from 1,100 to about 3,000, so that there is literal truth in the statement that MacNider grew up along with both the University and the community.

The following quotations from a tribute written by Chancellor Robert B. House shortly after MacNider's death are excellent expressions of what the writer of this memoir wishes this section to contain:

"Will MacNider was the most completely identified personality in body, mind and spirit with Chapel Hill and its environs and its people, and with the University of North Carolina of any man with whom we have been associated. . . . I found him attuned to every main value the University stood for and able to convey to students the spirit and feeling of what education was all about.

"He was almost a life-long member of the University Advisory Committee. . . . I know of nothing of any significance in any department or field of University effort which Dr. MacNider had not lovingly and thoughtfully considered and advised on with perfect frankness and sincerity.

"I think that such beauty as architecture has given to our campus, such protection of woods and natural beauty here as has been achieved by zoning, owe much to Bill MacNider. . . . He was almost all his life a member of the University Building Committee, instant and stalwart in support of appropriateness, dignity and beauty."

In 1946, his colleague Dr. Coppridge wrote:

"In 1936 the life of the Medical School was threatened because of certain actions taken by national standardizing bodies, directed against the two-year medical schools of this country. Dr. MacNider, in an able and energetic presentation of the case for the two-year schools, won for them the approval that was necessary for their continued existence. He argued sanely and eloquently that there is a place in any university for the teaching of basic medical sciences, and the weight of his arguments has held until this day."

One of the great material benefits which issued from Dr. MacNider's devotion to the University was a new laboratory building for the medical sciences, for it was largely through his efforts while Dean of the Medical School from 1937 to 1940 that the funds required for its construction were acquired. After his death, by action of the trustees, the building was named for him.

Because of the part which MacNider played for half a century in the growth of his University it seems fitting that this account of his relations with it should close with a sentence written by the Louisville newspaper editor, Mark F. Ethridge, in 1939:

"When the historian comes 50 years from now, to deal with the Southern Renaissance, he will have to say, as he can say in all truth, that its primary impulse came from, and its greatest influence was the University of North Carolina. This little City of Chapel Hill has become indeed the Capital of the Southern Mind."

What is now to be written concerning MacNider's influence upon the students who made up his classes in the Medical School relates to the dominant element of his life work. Forty-four successive classes received instruction and inspiration from him. The core of his educational philosophy was put into words written in 1909: "The development of such a course [pharmacology] depends primarily upon the intensity of the desire on the part of the instructor to aid in turning out better medical men; and secondly it depends upon the appreciation of animal work when it is carefully and accurately done by the student."

That sentence shows that his aim was to help his students to become good doctors—not research scientists; but it gives no hint of the intimacy with which he entered into their lives and gained their friendship. Because the Chapel Hill school offered only a two-year course, it was necessary that his students, on leaving should gain admission to a four-year school elsewhere in order to achieve the M. D. degree. Wherever they went, the quality of their two-year training caused North Carolina students to be regarded as preferred candidates; they bore an impress clearly recognizable as that of MacNider's sincerity of character and love of truth. He told his students, "You must not be satisfied with the statements of others, but you must doubt, you must inquire and you must express your misgivings by tests." Again and again he sought to inspire them with humility and reverence in the face of the mysteries of living creatures. In their third and fourth year work in other schools, they found it hard to tolerate teachings which seemed to run counter to what they had learned from him. Their lasting trust in him and his friendship brought many of them back to him in later years for counsel in their difficulties.

When he retired from teaching in 1950, a former pupil, then in the armed forces overseas, wrote: "I feel sure that if you could know the real place you have in the hearts of forty-four years of doctors you would seek no other reward and no other justification for having taught so long, for having been."

And the medical class of 1949 gave him a scroll, signed by each member:

"Throughout the lifetime of a student of medicine he attends many classes, listens to innumerable lectures, is instructed by countless individuals. Occasionally, indeed rarely, it falls his privilege to be associated with some truly outstanding personality, a person whose influence is woven into the pattern of the student's life.

"We, the class of Nineteen Hundred Forty-nine, desirous of recognizing such a man as this, do hereby present this certificate of appreciation to:

DR. WILLIAM DEBERNIERE MACNIDER

"Though our association has been brief, he has given to us a glimpse of the knowledge which is never found on the printed page of a text-book or medical journal. He has taught us pride without snobbishness, and devotion to a concept without bigotry. With his own life, he has presented us with an ideal of Christian counsellor, loyal friend and truly good physician."

One of the students was responsible for the conception which led to the publication in 1953 of a book, *The Good Doctor,* in which selections from MacNider's writings are assembled, together with tributes from University officials; some of the quotations in this memoir have been taken from that book.

What remains to be written concerns personal relations with family, friends, and the community of which he was so intimate a part. After his marriage in 1918 to Sarah Jane Foard of Salisbury, N. C., the old home in which he was born was given up and he and his wife moved, with his mother and his aunt, to the house on East Franklin Street which they occupied during the rest of his life. It became a center of hospitality for his friends in Chapel Hill, a symbol of southern welcome to his friends from the north. His wife was a never-failing support and ally; her reticent Presbyterian uprightness was a foil to the seeming insouciance with which he often masked his Episcopalian faith.

They had no money to waste. He tended to be extravagant in such things as books, orchestral and operatic records, travel to scientific meetings, and entertainment; she was the one who, knowing what those things meant to him and sharing his enjoyment of them, at the same time knew how to keep the family economy in balance.

It was in that home that his daughter, Sallie Foard, was born; she became his most intimate companion in everything which exercised his mind and heart.

MacNider was possessed of a deeply religious belief, which unobtrusively permeated all of his relationships. He loved the Episcopal Church of which he was a vestryman, and found solace in its service. On one Good Friday he is known to have dismissed his class and led them to the service there. He seemed to be on terms of informal intimacy with Jesus, often startling, as when, in a quandary, he would blurt out the question "What would He do in such a case?" In this he saw no inconsistency with good fellowship and conviviality.

It has already been said that he approached his own and his students' experiments with an attitude of reverence for the mysteries which they disclosed—to him they were "manifestations of the presence and the wisdom of God."

Reference has been made to his love of nature. The environs of Chapel Hill, especially when the dogwoods were in bloom, were a source of intoxicating joy; his garden, planted and cultivated by himself, was his delight. In the April before his death he wrote, "Just at the rear of our home is a triangular piece of land, 300 by 100 feet at the base. Hundreds of jonquils, the bulbs planted five years ago, are now in bloom, not bedded, but free and happy. On either side of the triangle a japonica hedge, also in full bloom." From that garden, every spring, he carried flowers to his near-by friends and sent them to those more distant. Regularly, too, he sent his marigold seeds to the people he loved, not only in this country but abroad. His love of flowers was part of his faith.

MacNider's death in May, 1951, brought mourning not only to hosts of his friends in Chapel Hill, where he had become a landmark of integrity and helpfulness, but also to many others more remote. The comment then most frequently spoken and written was, "He had a genius for friendship." The secret of this was not only his warmth of heart, his love for and interest in people, but also in his unique willingness to give them expression. In his own words, "When I curb my heart I am unhappy."

"The whole earth is a sepulchre of famous men; and their story is not graven only on the stone over their native earth, but lives on, far away, without visible symbol, woven into the stuff of other mens' lives."

KEY TO ABBREVIATIONS

Am. J. Med. Sci. = American Journal of Medical Sciences
Am. J. Phys. = American Journal of Physiology
Am. J. Surg. = American Journal of Surgery
Ann. Int. Med. = Annals of Internal Medicine
Arch. Int. Med. = Archives of Internal Medicine
Boston Med. Surg. J. = Boston Medical and Surgical Journal
Bull. J. H. Hosp. = Bulletin of the Johns Hopkins Hospital
Charlotte Med. J. = Charlotte (N. C.) Medical Journal
J. A. Am. Med. Coll. = Journal of the Association of American Medical Colleges
J.A.M.A. = Journal of the American Medical Association
J. E. M. Sci. Soc. = Journal of the Elisha Mitchell Scientific Society
J. Exp. Med. = Journal of Experimental Medicine
J. Geront. = Journal of Gerontology
J. Med. Res. = Journal of Medical Research
J. Metab. Res. = Journal of Metabolic Research
J. Pharmacol. = Journal of Pharmacology and Experimental Therapeutics
J. S. C. Med. A. = Journal of the South Carolina Medical Asssociation
Ky. M. J. = Kentucky Medical Journal
N. C. Med. J. = North Carolina Medical Journal
N. Y. J. Med. = New York State Journal of Medicine
N. Y. Med. J. = New York Medical Journal
Penn. Med. J. = Pennsylvania Medical Journal
Physiol. Rev. = Physiological Reviews
Prensa Med. Mex. = La Prensa Medica Mexicana. Mexico, D.F.
Proc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine
Sci. Monthly = Scientific Monthly
S. G. O. = Surgery, Gynecology and Obstetrics
South. Med. J. = Southern Medical Journal
South. Med. Surg. = Southern Medicine and Surgery
Trans. Assn. Am. Phys. = Transactions of the Association of American Physicians
Trans. Conf. Liver Injury = Conference on Liver Injury. Transactions.
Trans. Med. Soc. N. C. = Transactions of the Medical Society of the State of North Carolina

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Elmer D. Merrill

ELMER DREW MERRILL

October 15, 1876—February 25, 1956

BY WILLIAM J. ROBBINS

ELMER DREW MERRILL was born at East Auburn, Maine, October 15, 1876, and died in the Lemuel Shattuck Hospital, Forest Hills, Massachusetts, February 25, 1956, at the age of seventy-nine. Few American botanists had as long and distinguished a career or were as well-known and widely honored.

His parents and immediate ancestors were farmers, fishermen, factory workers, and the like, upright and industrious but with limited means, culture, and outlook. His father was a direct descendant of Nathaniel Merrill, the first immigrant of that name who settled in Ipswich (Newbury), Massachusetts in 1635. His grandmother White was believed to have been descended from Peregrine White of the Plymouth Colony. His immediate ancestry was of English (White), Scottish (Cummings), and French (Merrill, Noyes) origin.

Both sides of his family evidenced the adventurous and pioneering spirit which characterized Merrill's career. His grandfather Noyes was a "forty-niner" who left his young children in charge of his wife and made the long journey to California via Panama, returning to Maine after a short and financially unsuccessful stay in California. His father ran away to sea at the age of fourteen, shipping as a cabin boy to the Orient via Cape Horn.

East Auburn, in which Merrill spent his early years, is located about three miles from Auburn, Maine. It included one general store, a school, a meeting hall, a church (Baptist), and about fifty houses. At the outlet of Lake Auburn there was a sawmill, a furniture factory, and a grist mill. The village was made up of farmers and workers in the shoe factories of Auburn. Few people in it had traveled farther than Boston, Massachusetts. The community was not particularly religious; most residents took their religious duties lightly; Merrill's parents were not churchgoers and he himself never attended church or Sunday School. He was brought up, in his own words, more or less as a "heathen."

Merrill was one of six children, having two older brothers, a sister, a twin brother (Dana T.), and one brother who died in infancy. His mother, Mary Adelaide (Noyes) Merrill (born about 1845, died 1893) was very active, energetic, and ambitious for her sons. His father, Daniel C. (born 1837, died 1925) followed the sea for some fifteen years and then settled in East Auburn, where he worked in the shoe factories, farmed, and made occasional fishing trips to the Grand Banks. His father was impatient at times and emphatic in his language, and would remark when a tool had disappeared: "Those damned twins, they scatter things from hell to breakfast."

The twins assisted their grandfather Noyes in the farming operations of milking; haying; planting potatoes, beans, turnips, and other vegetable crops; hoeing and harvesting them, and of course picking and removing rocks which they firmly believed grew like potatoes. Merrill saw a good deal of his grandfather Noyes, tall, straight, with abundant black hair, heavy eyebrows, patriarchal gray beard, and shaven upper lip, a man of character and of pronounced opinions. The farming experience was doubtless responsible in part for Merrill's later interest in cultivated plants and their origin.

Although Merrill's older brothers and sister ended their formal education with grammar school, he and his twin brother continued through high school, influenced by their teacher in the village school, Miss Margaret Wilson, and by their mother. The first year of high school was completed in the village school at East Auburn under the supervision of Miss Wilson in a class of five or six pupils, but the last three years were taken in the Auburn High School three miles from the Merrill home. Each school day Merrill walked to school and back, never missing a day or arriving late, even though the trip was made on occasion on snowshoes and he might find the school dismissed because of inclement weather. This school experience Merrill believed established in him the quality of persistence to which he assigned most of the success which came to him in later years. The scholastic requirements of the high school were not high; Merrill had almost no home studying to do and had elected the so-called English course with no Latin nor Greek, a decision which he was to regret keenly in later life.

In addition to helping with the farm work and going to school, Merrill early developed an interest in natural history and in collecting. He built up a respectable collection of birds' eggs, collected rocks and minerals, Indian relics, local woods, and shelf fungi, which he assembled years before he realized they were plant forms. Even before he reached high school he had become interested in collecting and naming plants, though he had no manual of the local flora and depended on the common names in the few publications available.

Merrill had no intention of continuing his education beyond high school, but gradually the idea of college grew because a number of his friends planned a college career and because of the influence of his mother, who had left a small legacy specifically for Merrill's college education. With no preparation in Latin or Greek, the classical colleges of New England were closed to him and, therefore, he and his twin brother decided to study engineering and in the fall of 1894 entered the Maine State College at Orono, a land grant institution which three years later became the University of Maine. Maine State College was a small institution with about two hundred students, most of whom were taking engineering, but the freshman class in which Merrill enrolled was relatively large, about ninety, of whom about half eventually completed the four years.

Before the end of Merrill's first year in college, however, he decided that engineering required too much mathematics and at the beginning of the second year he transferred to the general science course. Merrill says of his college experience that he made no striking record; he was not an athlete, not a leader because he was by nature diffident and lacked confidence in himself, not a hard student, and was restricted in his activities because of limited funds. In addition to the small legacy from his mother, Merrill borrowed money and spent his vacations earning more in the state fish hatchery.

His early interest in natural history and collecting continued in college. He devoted a good deal of attention to biology, especially the classification of flowering plants, stimulated by Professor F. L. Harvey, who taught botany, zoology, entomology, and geology and inspired Merrill to field work and research, especially in the lower groups of plants. In fact, the only formal course in botany taken by Merrill was in the cryptogams. During his college career he collected on Mount Washington and Mount Katahdin, and by the time he left Maine he had accumulated a private herbarium of more than 2,000 specimens in all groups, which he later gave to the New England Botanical Club.

Merrill was graduated as valedictorian of his class with a Bachelor of Science degree in 1898 and returned the following September as Assistant in Natural Science at a salary of $250.00 for nine months. No formal graduate work was offered at the University of Maine, so Merrill took courses to round out his undergraduate program and followed his own bent in the pursuit of systematic botany, but with little or no supervision.

In the spring of 1899, Merrill took a United States Civil Service examination for a position as Assistant Agrostologist in the United States Department of Agriculture. However, to be certain of some employment he accepted a fellowship (board, room, and laundry) in plant pathology at the Experiment Station at Geneva, New York. On reporting there for duty in July he found a letter appointing him as Assistant Agrostologist with the Department of Agriculture at an annual salary of $1,200 and, against the advice of Dr. W. H. Jordan, Director of the Geneva Station, accepted the appointment and reported in Washington, D. C., for duty on July 7, 1899.

In Washington, Merrill served as an assistant to F. Lamson-Scribner, then the leading authority in America on the classification of grasses. There, during two and a half years he gained a knowledge of herbarium methods, of literature on the classification of the grasses, of methodology in dealing with material and descriptions, of problems of nomenclature, and of the principles of taxonomy, and a wide acquaintance with the grasses of North America. In a sense this period was a graduate course in which Merrill was largely his own teacher, utilizing the resources of an active and extensive herbarium. Field experience in Wyoming, Idaho, and Montana supplemented his training in Washington.

In spite of his interest in systematic botany, Merrill had not yet settled on his eventual career, and enrolled in the evening classes of the Medical School of George Washington University, where he completed three semesters of work. It is possible that he might have continued his medical training and become a physician, but in 1901 the Philippine Commission authorized the establishment of the Insular Bureau of Agriculture in Manila, and Merrill was offered and accepted the post of Botanist at an annual salary of $2,000. He arrived in Manila in April, 1902, where he remained for nearly twenty-two years, and there the course of his life work was firmly fixed.

The situation Merrill found in Manila was most discouraging. He began work in a vacant building without even a chair or table, not to speak of botanical publications or specimens. The botanical collections assembled by Vidal from 1876 to 1888 had been destroyed by fire in 1897, together with the entire botanical library; the collection of botanical literature at the Jardin Botanico had disappeared during the American occupation of Manila, and the duplicate set of Vidal's herbarium in the Museo Biblioteca had also disappeared; the botanical material assembled by Fernandez-Villar for the third edition of Blanco's *Flora de Filipinas* had been destroyed when the building in which it was stored was burned by American troops in 1899. Some botanical literature had been acquired and some plants (usually unnamed) collected by the Bureau of Forestry. Truly, to say the least, a most discouraging outlook. But when Merrill left the Philippines in 1923, the herbarium contained 275,000 mounted sheets, two thirds Philippine and one third external, chiefly Malaysian, and the library had become botanically unsurpassed in the East. These accumulations were burned by the Japanese Army one day before the liberation of Manila in 1946. The liberal policy Merrill had followed in the distribution of duplicate specimens enabled him, then at Harvard, to locate material in American and European herbaria and to aid Dr. Eduardo Quisumbing, an outstanding Philippine botanist trained by Merrill, to begin rebuilding.

Merrill found that he was expected to devote his attention to "practical" work, but decided to build a reference collection of botanical specimens and acquire the necessary literature. He began by collecting specimens of all the weeds in the back yard of the office building.

A few months after Merrill's arrival in the Philippines, he was made Botanist of the Bureau of Forestry in addition to his position with the Bureau of Agriculture and divided his time between forestry and agriculture. Various reorganizations of the scientific work in the Philippines resulted in his appointment in 1903 as Botanist, Bureau of Government Laboratories; in 1906 as Botanist, Bureau of Science; in 1919 as Acting Director, Bureau of Science, and a few months later as Director, Bureau of Science. Merrill also served from 1912 to 1918 as Associate Professor, later Professor of Botany, University of the Philippines, on a "half time" basis and taught from eighteen to thirty-six hours a week during the academic year. Soon after his arrival in the Philippines, Merrill decided to prepare a Flora of the Philippines, a project on which he embarked with enthusiasm and determination. The extent of this ambitious project may be realized when the flora of the Philippines is compared with other regions. He estimated the Philippines to contain in excess of 10,000 species, while Great Britain and Ireland have less than 2,500, New Zealand less than 2,000, and the northeastern United States about 4,500. The vast amount of effort necessary to assemble and digest the literature and reference material, to master the problems of nomenclature in the major groups, to collect the plants, to determine their geographical distribution, their relationships and interrelationships, and to prepare descriptions and critical notes on thousands of new species is appalling. In addition, after the first ten years, much of his time and energy was absorbed by his teaching and by his administrative responsibilities, especially as Director of the Bureau of Science.

Most of the scientific and control work for the Philippines was centered in the Bureau of Science, including medical research, public health laboratory work, manufacture of vaccines, organic and inorganic chemistry, standardization of weights and measures, testing of structural materials, geology and mining, fisheries, zoology, ornithology, entomology, botany, plant pathology and physiology, and anthropology. A reporter who interviewed Merrill in 1940 expressed the activities of the Bureau of Science thus: "The Director of the Bureau of Science does everything from telling the public what to do for a dog bite to where to drill for oil."

Merrill increased his staff, trained native collectors, gladly accepted the material collected by the forestry service, arranged contacts abroad, exchanged material, accumulated the essential literature, interested authorities elsewhere in the identification of special groups of plants, and spent considerable time in the field. But in time he realized that the preparation of a descriptive flora was beyond his means and converted the proposed flora into an enumeration of Philippine flowering plants, which was issued between 1922 and 1926 and consisted of 2,136 pages in four volumes. The labor involved in this, though considerably less than that which would have been required for the flora, may be judged from the following figures: 8,120 species were admitted, about 11,200 synonyms were reduced, and 13,600 vernacular names recorded. The review assessed the specific endemism of the Philippine archipelago, discussed linkages with other floras, and made a valuable contribution to biogeography.

Merrill also came to realize that extra-Philippine material was necessary for good work on the Philippine flora. While numerous exchanges were arranged it became evident that the material most desired could not be secured from those sources alone. He therefore gradually developed extra-Philippine exploration, and between 1910 and 1920 important collections were made by the staff in Indo-China, China, Guam, Borneo, and Amboina.

The desire for extra-Philippine material came partly because of the urgent need for comparative material from adjacent regions and also because some species described earlier by Blanco, Rumphius, and others could not accurately be interpreted in the absence of material from the historical localities in which the collections had been made. Merrill decided that Blanco's numerous and inadequately described species could be more accurately interpreted from general collections made in the regions familiar to Blanco, from which he had secured the actual specimens on which his descriptions were based; there were no specimens extant representing the numerous species he had described and the published descriptions were inadequate. A similar problem existed for Rumphius' Herbarium Amboinense. With the aid of C. B. Robinson, who collected extensively over Blanco's area, Merrill made close acquaintance with the flora of Amboina. He obtained from the Dutch material which connected his knowledge with that of the younger Burman, and for Loureiro he obtained collections from Hue in Annam and visited Canton himself.

This method of identifying previously described plant species by a study of the plant populations from which they had been drawn when the method of using types could not be applied is a landmark in botanical history for, though others had thought of the procedure, as is pointed out by Burkill, none had been able to consummate it.

In addition to the enumeration and critical studies of the species of Blanco and Rumphius, Merrill prepared a flora of Manila of 490 pages, a systematic enumeration of the plants of Guam, and became involved in the identification of Bornean plants, literature for which was widely scattered. He therefore commenced the preparation of a card catalogue of all references to the Bornean flora by species, which eventually resulted in the publication of a bibliography of Bornean botany containing 479 titles and later a *Bibliographic Enumeration of Bornean Plants,* a volume of 637 pages.

Merrill also became interested in the flora of southeastern China, making two trips to Canton and one to Nanking, each of one month's duration. Considerable collecting was accomplished, a knowledge of field conditions in eastern and southern China was gained, and botanical research in Chinese institutions was stimulated.

Merrill's administrative position as Director of the Bureau of Science brought him into contact with scientists in fields other than botanical taxonomy. In preparing in 1903 a *Dictionary of Philippine Plant Names* as an aid to foresters, he noted that American plant names had been brought to the Philippines with American plants and that other names had come from India and China. His travels broadened his outlook and presented problems on plant distribution. These influences and others expanded the region of his interest from the Philippines to the entire Pacific area and even beyond and from plant taxonomy to geology, hydrography and climatology, to those phases of ethno-botany which concerned the origin of cultivated plants in relation to specific civilizations, to certain phases of comparative philology especially Sanskritic, Chinese and Aztec plant names actually used in the Philippines and even to leprosy and its transmission. He became convinced that pre-Columbian agriculture in America was based wholly on native American plants and animals and effectively challenged the extreme diffusionists, those who assumed a single center as the source of civilization. Interest in the origin of cultivated plants and their distribution and in the historical aspects of botany continued throughout his career.

In 1923 Merrill was offered the deanship of the College of Agriculture of the University of California. In spite of the attractions that the Philippines held for him as a field of work, he was on an annual appointment and had the uneasy feeling that there was no future, even as there was no assured tenure nor provision for a retirement pension. He also had his family to consider.

In May, 1907, Merrill had married, in Manila, Mary Augusta Sperry of Illinois and the newly married couple immediately sailed for the United States by way of China and Japan. A few months were spent in Washington, D. C., and a short trip made to New England. On the way back to Manila, about two months were spent at Kew and at the British Museum, followed by visits to Leiden, Berlin, Geneva, and Florence; at each of these places types of Philippine species were examined. By April, 1908, Merrill and his wife were back in Manila. A daughter, Lynne, was born in Manila on February 12, 1909, followed by a son, Dudley Sperry, born on September 21, 1912, and a second son, Wilmans Noyes, born December 21, 1914, who died at the age of less than two months. This tragedy and other considerations induced the Merrills to conclude that Manila was not the proper place to raise a family, and in 1915 when Merrill took a short leave in Washington, D. C., he left his wife and family there when he returned to Manila. He was not to be with his family again for the next eight years, except for a period of accrued leave in 1920–21. In fact, Merrill did not see his daughter, Ann, born in Washington, D. C., August 8, 1916, until she was five years old. If he had had no family responsibilities he would probably have remained in the Philippines, where considerable pressure to retain his services was brought to bear and where his heart lay with the plants of that archipelago. However, he accepted the appointment at California and assumed his new duties in the early part of 1924.

Leonard Wood, Governor-General of the Philippine Islands, wrote Merrill on his departure for California as follows:

"Upon your resignation as Director of the Bureau of Science and your withdrawal from the public service of the Philippine Government, I wish to commend you in the strongest terms and thank you for the work which you have done for the Islands during the long period of service here.

"When I was here as military commander of the Philippines Division from 1905 to 1908 you were keen to participate, and did participate, in various difficult reconnoitering expeditions, involving much hard work and exposure; notably the ascent of some of our highest and most difficult mountains—a work in which you were associated with the late Major Mearns of the Medical Corps of the Army.

"You have done first class work in everything you have attempted and have gained the confidence, respect and support of those with whom you have come in contact. You have done much to build up the insular service and have added a vast amount of valuable information to our knowledge of the flora and fauna of the Islands.

"Your conduct of the Bureau of Science served as an inspiration to all who worked under you and did much to re-establish this institution in public confidence.

"Your resignation results in a great loss to the Philippine public service—one which will be keenly felt and creates a vacancy which will be extremely difficult to fill. You will be missed both officially and personally. I feel that the University of California is to be congratulated on securing your services.

"With every best wish."

(*Signed*) Leonard Wood
Governor-General

Many problems faced Merrill as Dean of the College of Agriculture. There were internal and external dissensions arising in part from rapid growth of the College and in part from a tendency to consider that it was not an integral part of the University. The faculty included approximately 350 individuals, and the annual budget was $1,800,000. Merrill felt that he lacked experience with academic or research problems in agriculture, and that he knew little of the special problems of the College of Agriculture, and still less of those peculiar to California. Within less than a year he was made Director of the Agricultural Experiment Station in addition to his duties as Dean of the College of Agriculture.

Merrill stressed that the College of Agriculture was and should continue to be an integral part of the University and that the standards of both instruction and research should be raised. All junior members of the staff were urged and encouraged to undertake graduate work for advanced degrees. Gradually certain divisions were eliminated and the work combined with other existing ones, or new, more comprehensive units were established. Outlying units such as the University Farm at Davis and the Citrus Experiment Station at Riverside were made as autonomous as possible. Promotions were made strictly on merit, new appointments were predicated on fundamental training, with the Ph. D. or its equivalent as a basic requirement in most fields. In research the fundamental aspects were stressed and long-term projects were favored, and the entire curriculum of the College of Agriculture was revised with the aim of a university education on an agricultural basis as opposed to vocational instruction in agriculture.

During the six years that Merrill served as Dean of Agriculture at the University of California, he devoted all his spare time to work on systematic botany and to building up the oriental research herbarium of the University. This work in systematic botany was Merrill's safety valve for, once in the herbarium, early in the morning, at noon, after office hours, or on Sundays and holidays, he immediately forgot his administrative problems. He added some 110,000 sheets to the University herbarium, prepared and published a volume of 316 pages on the flora of Borneo, and wrote numerous short papers on the plants of China, Borneo, and the Philippines.

In 1926 a movement was initiated to establish a botanical garden in Los Angeles and Merrill was asked to become a member of the Garden Foundation. The plan involved the purchase, at a nominal valuation, of a large tract of some 4,500 acres in Mandeville Canyon, Sierra Madre Mountains, which was to be financed by a bond issue.

About 800 acres in the center of the tract were to be retained for development as a botanical garden, which was to be financed from the sale of surrounding acreage for residential purposes. The possibility of the establishment and endowment of a large botanical garden under most advantageous climatic conditions greatly intrigued Merrill, and he accepted the directorship of this embryonic institution on the basis of a part-time leave from the University of California. It soon became evident that the Los Angeles project probably could not be consummated on the basis of the original plans, but Merrill continued his connection with it until he left California at the close of 1929.

In September, 1929, Merrill accepted an appointment as Director of The New York Botanical Garden and Professor of Botany at Columbia University. He felt that most of the specific objectives at California had been accomplished. The perplexing problems of the institution had been settled to a substantial degree; the staff had been increased; material equipment had been greatly enlarged; the annual budget had been augmented. New buildings had been provided and policies established which met with the general support of the industry and of the institution. However, Merrill considered that if his fate was to continue in administrative work he would prefer to do such work in the botanical field and he believed that in New York he would have more time available for botanical work. He felt also that there was an opportunity to make The New York Botanical Garden a still greater institution than it had been. He therefore left California with the pleasant feeling that his departure was regretted by the administration of the University, by the agricultural public and its leaders, by the staff of the University as a whole, and by his immediate colleagues in the College of Agriculture. Dr. C. B. Lipman, Dean of the Graduate Division of the University of California, wrote:

"The resignation of Dr. E. D. Merrill from the position of Dean of the College of Agriculture and Director of the Agricultural Experiment Station at the University of California, is an occasion for the deepest regret to all those who have the interests at heart of the University in general and of the College of Agriculture in particular. It is given to few men to carry the burdens of an important office with numerous and complicated problems over a period of years, to close their labors in such an office on terms of friendship with all with whom they come in contact and with themselves. Such, however, is strictly true in the case of Dean Merrill. In the period of about six years during which he has held this very important position in the University of California, Dean Merrill has exhibited in high degree a combination of qualities which are rarely found in one individual. His quickness of perception, his unfailing patience and courtesy, his great store of common sense, his promptness in taking action, his approachableness, and consideration of others have won for him the admiration and high esteem of his colleagues in the administration of the University and of those on the faculty. His enviable record as a scientist and administrator are too well known to need repetition here, but four stages of his career may be mentioned as contributing to those fine qualities of leadership to which I have referred above.

"The first of these stages concerns his early life culminating in his graduation at the University of Maine where he attained to the sterling characteristics which characterize the natives of that rugged state; namely, self-reliance, honesty, providence, directness of manner, and industry. The second stage of his career covers a period of some eighteen years as a systematic botanist in the Philippines and neighboring lands. There he learned the value of intensive application and concentration upon the task to which he had set himself of gaining knowledge on tropical flora, culminating in a grasp of that subject which makes him a master and authority in that field of systematic botany and most highly regarded American botanist in the systematic field. In the third stage of his career, to the extent of four or five years, he was concerned in addition to botanical study with directorship of the Bureau of Science in Manila. Here his inherent qualities for successful administration became manifest. There, as at the University of California, he succeeded in solving problems without friction and in earning the devoted friendship of his colleagues and other co-workers. The fourth stage of his career to the present has been as Dean and Director of the College of Agriculture at the University of California, where he has been instrumental in establishing one of the best sets of curricula for a college of agriculture which are available in the United States, and where he has encouraged and stimulated in a sympathetic and most effective manner the prosecution of research on fundamental problems which underlie the science of agriculture.

"It is fitting that as he takes leave of us to take up the exalted position of Director of the New York Botanical Garden, we of the University of California record, not only our deep regret at losing him, but also our profound appreciation of his remarkable contribution to the success and effectiveness of the program of the College of Agriculture, of the scientific activity of the University in general, of our gratitude for the friendship and sympathy which he has shown to his colleagues unfailingly and of the high regard which we all entertain for him as a scholar, a scientist and, above all, a lovable human being. Dean Merrill carries with him to his new position in New York our hearty good wishes for his success during the long life which we all hope still stretches out before him. We wish him Godspeed."

Merrill accepted the appointment as Director of The New York Botanical Garden just before the 1929 depression, with promises of extensive support and with the anticipation of amplifying the work of the institution. He reported after the depression and found himself in an institution inadequately financed with obsolete and worn-out equipment and with a heavy overdraft on capital funds used for operating expenses. From a peak income of $445,000 in 1931 the income was reduced to $340,000 by 1934. Drastic economies, accomplished by a general reduction in salaries, elimination of positions, and reduction of expenses were necessary. However, beginning in November, 1930, assistance of various types from city, state, and federal relief agencies made it possible to initiate extensive outside projects covering the general rehabilitation of buildings, grounds, and plantings, and to accomplish a substantial improvement in the library and herbarium. Mounting was speeded up from approximately 10,000 sheets per year to as high as 80,000 sheets, all reserve collections from various parts of the world were sorted, poisoned, mounted, and distributed. The entire herbarium was rearranged. The most significant accomplishment was the policy of incorporating clipped or typed original descriptions and critical notes into the herbarium. Approximately 300,000 of these items were added, thus incorporating library data into the herbarium. Time not required for administrative duties and meeting obligations to various botanical organizations was devoted to accumulating and studying collections of plants from various parts of China, Formosa, India, Siberia, Malaysia, the Philippines, Micronesia, and Polynesia, and to the preparation of numerous papers based on these collections. The largest and most comprehensive of these was that on Louriero, a 450-page quarto volume.

When he came to New York in 1930, Merrill had felt that the move to The New York Botanical Garden was his last and that he was in a position where his absorption with systematic botany could be pursued. However, in 1935 he was offered and accepted an appointment as Professor of Botany and Administrator of Botanical Collections at Harvard University, a new position created for the supervision of the eight separately endowed Harvard botanical units—the Bussey Institution, the Gray Herbarium, the Farlow Herbarium and Library, the Botanical Garden, the Botanical Museum, the Arnold Arboretum (including the Atkins Institution in Cuba), and the Harvard Forest at Petersham. A ninth unit was added in 1937 with the organization of the Maria Moors Cabot Foundation for Botanical Research.

He accepted this appointment with the realization that he would have to give up the marvelous tool for work on oriental botany which he had built in New York, change his personal plans for botanical research, start his career a fifth time under new and unknown surroundings, and for a fourth time undertake a most complex administrative problem involving organization and correlation.

On his departure from The New York Botanical Garden, the Board of Managers passed the following resolution:

"WHEREAS, Dr. Elmer Drew Merrill, Director of The New York Botanical Garden since January 1, 1930, has tendered to the Board of Managers of the Garden his resignation of this post, effective on October 1, 1935, in order to accept appointment as Professor of Botany and Administrator of Botanical Collections at Harvard University, therefore,

"BE IT RESOLVED, by the Managers of The New York Botanical Garden, that they are highly appreciative of the very efficient services that Dr. Merrill has rendered to the Garden during his tenure of office of somewhat more than five and a half years; that they have noted, in particular, the promptness and foresight with which he has secured for the Garden assignment of workers and appropriations of funds by various emergency relief and employment bureaus for general assistance and for much needed repairs and improvements; that they have observed with gratification the development of horticultural features which have made the Garden increasingly attractive to the general public; that they have noted, with wonder and admiration, Dr. Merrill's ability, in spite of exacting executive duties, to continue his systematic studies of Oriental plants, studies which have made him the outstanding leader in this field; that they have observed with satisfaction the honors that have been bestowed upon him by American, foreign and international scientific organizations. While the Managers greatly regret his going, they extend to Doctor Merrill their very best wishes for happiness in his new field and for a most successful continuation of his distinguished career."

A year after his arrival at Harvard, Merrill became also the Arnold Professor of Botany, and in 1937 Director of the Arnold Arboretum.

The purpose of the appointment of an Administrator of Botanical Collections was to draw together the semi-autonomous botanical institutions at Harvard, eliminate duplication, and enhance their efficiency. For several reasons, mainly the Second World War and resulting uncertainties, the attainment of this objective went slowly.

In the meantime Merrill devoted the major part of his time to increasing the herbarium of the Arnold Arboretum and to research on Asiatic plants. Specimens in unprecedented quantities arrived from China, India, Indo-China, Burma, Siam, the Malay Peninsula, the Philippines, Java, Borneo, Australia, New Guinea, and other parts of the Far East, as well as from Mexico, Central America, the Antilles, and Africa. In a decade the herbarium was increased by 220,000 specimens.

Merrill continued to publish profusely, and in addition edited several facsimile editions of early botanical classics. His early interest in economic and historical botany was reawakened, and he wrote a number of articles dealing with the diffusion of domesticated and cultivated plants. He was also active during the war as a consultant on tropical botany to the Secretary of War, and wrote for the Survival Program of the armed forces a manual of poisonous and food plants of the jungles of the Pacific area.

During the latter part of the war years, a committee of Harvard botanists appointed by Merrill and by Professor Alden Dawson, Chairman of Harvard's Department of Biology, prepared an overall plan to bring Harvard's herbarium and botanical library facilities together in fireproof quarters at Cambridge. This plan was submitted to the Harvard Corporation and accepted. Merrill was at first in favor of the plan, but eventually came to believe that it was not in the best interest of the Arnold Arboretum and opposed it strongly before and after his retirement as Director of the Arnold Arboretum. Notwithstanding his opposition, the final plan was put into effect and a substantial part of the library and herbarium of the Arnold Arboretum was moved to the newly constructed building on the Cambridge campus. This, combined with a lingering illness, made Merrill's final years of life unhappy. He retired from his administrative post in July, 1946, in his seventieth year, but remained for two years as Arnold Professor of Botany. In 1948 he became Arnold Professor Emeritus, but continued his own research at Harvard and abroad as vigorously as increasing age and failing health permitted.

One of the major contributions during his retirement was *The Botany of Cook's Voyages*. While writing this book he was taken seriously ill and completed the work in 1954 under great difficulties between bouts of illness. The book is a monument to Merrill's determination. It deals critically and mercilessly with the extravagant theories propounded by some writers on the origin and dispersal of certain economic plants.

Merrill received many honors. He was awarded honorary degrees of Doctor of Science from the University of Maine in 1926 and from Harvard University in 1936, Doctor of Letters from the University of California in 1936 and from Yale University in 1951. In 1939 he was given the gold medal of the French Ministry of Agriculture and a diploma from the Société Nationale d'Acclimatation. In the same year the Linnean Society of London, of which he was a Foreign Member, decorated him with its medal, and in 1950 he was awarded the Geoffrey St. Hilaire medal and made a Commander in the Netherlands Order of Oranje Nassau. He was an honorary member of the Deutsche Botanische Gesellschaft, an honorary member of the Netherlands Botanical Society, and a member of the National Academy of Sciences and of the American Philosophical Society. He served as official U. S. delegate to the Fifth Pacific Science Congress in Vancouver in 1933, as President of the Botanical Society of America in 1934, as President of the Section of Taxonomy and Nomenclature of the Sixth International Botanical Congress in Amsterdam in 1936 and of the Seventh in Stockholm in 1950, as Acting President of the American Association for the Advancement of Science in 1931, and as President of the New England Botanical Club, 1937–1939, the American Society of Plant Taxonomists, 1946, and the International Union of Biological Sciences, 1935. He held membership in many scientific societies, including: American Academy of

Arts and Sciences (fellow), Philadelphia Academy of Natural Sciences, Académie des Sciences de l'Institut de France (correspondent), Torrey Botanical Club, Sigma Xi, Phi Beta Kappa, Alpha Zeta, Phi Kappa Sigma, Royal Horticultural Society of London, Edinburgh Botanical Society, Royal Society of Edinburgh, Universidad Nacional de La Plata (Académico Honorário), Malayan Branch of the Royal Asiatic Society, Muséum National d'Histoire Naturelle of Paris (correspondent), Nederlandse Botanische Vereniging, Kon. Nederlands Aardrijkskundig Genootschap, Naturhistorisches Museum of Vienna (correspondent), Svenska Vetenskaps Akademien, Institut Genevois, Société Botanique de France, Japanese Botanical Society, Peking Society of Natural History, and Royal Agricultural and Horticultural Society of India. In 1936, he was official guest of Harvard University at its Tercentenary Celebration. For a number of years he was a member of the Latin American Committee of Selection of the John Simon Guggenheim Foundation. He served at various times as a member of the board of directors or as trustee of a number of institutions and societies, such as the Escuela Agricola Panamericana in Honduras, the Gorgas Memorial Institute, the New York Horticultural Society, and the Board of Managers of The New York Botanical Garden.

Merrill was of medium height, slight of build, and blond, in contrast to his twin brother, Dana T., who was tall, and who had very dark eyes and hair. "His voice was sharp and clipped, characterized by a lasting and unmistakable Maine accent; his speech frank and blunt. He was prone to make quick-on-the-spot decisions. From earliest youth he was possessed of an unsatisfiable drive sometimes approaching brashness—the key to his great achievements. It was that drive so characteristic of Maine people—whether they spend their lives on their native farms or whether, like Merrill, they travel to parts foreign. It was that drive which, in an earlier period, sent the Maine clipper ships to all corners of the earth. And there is much in Merrill's career—his urge to see new lands, to seek out the unknown, to build great institutions for future generations—that can be likened to . . . the spirit of Maine. . . . For, though Merrill left his native habitat early in his career and never returned to practice his profession there, he remained always a State of Mainer" (R. E. Schultes, 1957).

Merrill was a man in a hurry who saw clearly a program of research which absorbed him, but which was greater than any individual could complete within the limits of a single lifetime. The demands of this program possessed him. It led him to make various innovations and modifications of conventional procedures in herbarium methods which increased efficiency in the use of this, for him, essential tool and to advocate briefer citations, one-name periodicals, and other means of economizing time and effort. It induced him, at least in part, to make quick decisions without long consideration of the pros and cons and to act at times without regard to the feelings of others. It occupied his spare time when ordinary men would have found administrative responsibilities more than enough. And yet with all his effort the horizon stretched out beyond his reach. Discussing in his latest book (*The Botany of Captain Cook's Voyages*) the contribution a study of pre-Linnean herbaria might make towards elucidating the place of origin of a plant species which is now more or less universally distributed, he wrote, "As I close my active career, one of my regrets is that I have not been able to exploit these promising possibilities."

It has been said that Merrill seldom went far below the surface, that he was content in most instances to classify the plants with which he dealt. This type of research was proper for the region he studied and was the only procedure which permitted him to do what he did in his lifetime. It is exactly this characteristic ability to deal superficially with extraordinarily large numbers of plants that makes so apt the epithet "the American Linnaeus" which has been applied to him. Actually, however, Merrill did "go below the surface." He recognized that classification was prerequisite for other investigations and the magnitude of the job he set for himself left little time to pursue anything else. But his studies of the floristic and faunistic relationships of the Philippines to other Malaysian areas, of the significance of vernacular plant names to the introduction of species, and of the origin of cultivated plants are examples of "below the surface" investigations carried out by Merrill.

In spite of his absorption with his speciality Merrill was not a recluse. Nothing pleased him more than to light his pipe and sit down to talk with a group of gardeners or with a student or his colleagues, mainly, of course, about plants. He played an active part in many organizations and valued the associations he made in them. He joined the Masonic order and eventually became a thirty-third degree Mason. He enjoyed an evening cocktail in his later years, and loved to have visitors and dinner guests. Though he had no hobbies outside his profession, he was interested in sports, especially baseball, football, and tennis. At Manila he was a member of the Columbia Club (eventually its President), and played tennis in the late afternoon, weather permitting. The autobiographical accounts of his adventures in collecting in the Philippines and in China reveal some of the human aspects of his character.

Merrill described over three thousand new species of Philippine, Polynesian, Chinese, Moluccan, and Bornean plants and was the author of more than five hundred technical papers and books. It has been estimated that he was responsible for adding nearly 1,000,000 herbarium specimens to the herbaria of the Bureau of Science of the Philippines, of the University of California, of The New York Botanical Garden, and of the Arnold Arboretum and other units at Harvard University, plus an undetermined number of duplicates distributed to other institutions. At least seven plant genera (*Merrillia Swingle, Merrilliobryum Brotherus, Merrilliodendron Kanehira, Merrilliopeltis Hennings, Merrillosphaera Shaw, Sinomerrillia Hu,* and *Elmerrillia Dandy*) are dedicated to Merrill, and some 220 binomials have the specific name dedicated to him. When Merrill referred to these names which immortalized him, he was accustomed, with a twinkle in his eye, to translate *Merrilliopeltis* as "Merrill's hide."

His energy was boundless. It was his habit, at the University of California, to arrive at the herbarium at 6:00 a.m. and work on shipments of plants until he left for the Dean's office at 9:00 a.m.

His knowledge of plants was prodigious. During the Second World War, soldiers collected plants in areas of the western Pacific and sent them to Merrill for identification, but because of military restrictions the place of collection could not be designated. On the basis of his acquaintance with the plants of the western Pacific, Merrill was frequently able to locate with uncanny accuracy the place from which such collections came. In one instance, for example, he spotted the place of collection on the island of Borneo within an area of fifty miles, an estimate confirmed after military restrictions had been lifted. To see him go through a collection of herbarium specimens from his chosen area and name the majority almost as rapidly as he picked them up was an education in itself.

His interest was not limited to taxonomy as such, but extended to phytogeography, plant migration, the origin and distribution of cultivated plants, and to ornamental horticulture. He played a major part in the introduction to the West in 1948 of *Metasequoia glyptostrobioides,* the "living fossil."

He had a gift for organization which was demonstrated by the administrative posts he held, the critical lists of flora and bibliographies he prepared, and the various improvements he introduced in the organization of herbaria.

He had a keen sense of humor and of the dramatic, and enjoyed telling and emphasizing the pertinent aspects of some incident. At The New York Botanical Garden he insisted on sitting in the front seat of an automobile because that was evidence of rank and "the Director was the rankest member of the staff." His sister-in-law, who confessed that all she knew of cooking was how to boil an egg, was labeled by Merrill thereafter "The Eggster." He fully appreciated the dramatic aspects of his arrival in England with pockets full of seeds of Metasequoia, which he casually pulled out and distributed to botanical associates, and of his discovery in the British Museum of unnamed remnants of the collections by Banks and Solander made on Captain Cook's first voyage around the world.

Although always ready to help anyone interested in plants, he had no hesitation in speaking frankly, critically, even bluntly. The boy who was "no leader, being naturally too diffident and having little confidence in my own abilities" changed with time to a man who, convinced in his own mind of the rightness of his judgment, had no hesitation in expressing it and fighting for it. This led some to consider him egotistical and vain, and sometimes aroused enmities. The vast majority of his associates recognized, however, that his decisions were not made on petty grounds and admired his drive and dedicated service to botanical science.

His reputation as a brilliant taxonomist, a builder of botanical collections, a dedicated student, and an able administrator was world wide. ". . . Merrill was an outstanding internationalist in botany. . . . the full impact of the international emphasis of his work will not wholly be appreciated for a quarter of a century. His influence as an international figure in botany will grow with the passing of the years" (R. E. Schultes, 1957).

His unique library of some 2,600 titles was given to The New York Botanical Garden with the provision that duplicates were to be sold. He requested that the proceeds, plus contributions from friends and associates, be used to establish a fund in his name to finance publication or a medal to be awarded to that individual within the entire field of botany, irrespective of race, creed, or nationality, who was considered to be worthy of such an award. This action was in accord with the interests to which he had devoted his life.

CHRONOLOGY

1876	Born at East Auburn, Maine, on October 15.
1894	Graduated from the Edward Little High School, Auburn, Maine. Entered the University of Maine.
1898	B. Sc., University of Maine; Valedictorian.
1899	First paper ("Notes on Maine Plants") published, in *Rhodora,* Vol. 1.
1898–99	Assistant, Dept. of Natural Science, University of Maine.
1899–1902	Assistant Agrostologist, U. S. Dept. of Agriculture, Washington, D. C.
1900–01	Student at George Washington University, Medical School.
1902–03	Botanist, Bureau of Agriculture and Forestry, Manila, P. I.
1902	Visits to Ceylon and Singapore. First trip to Buitenzorg, Java.
1903	*Dictionary of the Plant Names of the Philippine Islands* published.
1903–05	Botanist, Bureau of Government Laboratories, Manila, P. I.
1904	M. Sc. degree, University of Maine.
1904	"New and Noteworthy Philippine Plants" series initiated.
1905	Review of Blanco's plant species published.
1906–23	Botanist, Bureau of Science, Manila.
1906	Mount Halcon Expedition, one of a great many exploring expeditions in the Philippines between 1902 and 1923.
1906–23	*Philippine Journal of Science* established. This was greatly developed and in part edited by Dr. Merrill until he left Manila in 1923.
1907	Married Mary Augusta Sperry, Manila, P. I.—Children: Lynne, Dudley Sperry, Wilmans Noyes (dec.), Ann.
1907–08	First leave while in Manila: nearly three months spent in London, engaged in botanical work, with shorter visits to Leiden, Berlin, Geneva, and Florence.
1909	Fellow, American Association for the Advancement of Science.
1912–17	Associate Professor of Botany and Head of the Department, University of the Philippines (half-time appointment).
1912	*Flora of Manila* published.
1913	C. B. Robinson's Expedition to Amboina planned.
1913	Work on the Guam flora initiated.
1914	Second visit to Buitenzorg, to settle matters concerned with the death of C. B. Robinson in Amboina.
1914	Enumeration of Guam plants published.
1914–15	Second leave while in Manila, spent in Washington, D. C.
1915	Work on the Borneo flora initiated.
1916–17	Collecting trips in Kwangtung Province, China.

1917–19	Professor of Botany, University of the Philippines (half-time appointment).
1917	*An Interpretation of Rumphius' Herbarium Amboinense* published.
1918	*Species Blancoanae* published.
1918	First of many papers on the flora of China published.
1919	Acting Director, Bureau of Science, Manila.
1919	Corresponding Member, Malayan Branch, Royal Asiatic Society, Singapore.
1919–23	Director, Bureau of Science, Manila.
1919–23	Professorial Lecturer, University of the Philippines.
1919–23	Editor, *Philippine Journal of Science.*
1920	Honorary Consulting Botanist, Bishop Museum, Honolulu.
1920	Collecting trip to Anwhei and Chekiang Provinces, China.
1920–21	Third leave. Attended First Pan-Pacific Congress at Honolulu, spent remaining time in California.
1921	*Bibliographic Enumeration of Bornean Plants* published.
1921	First of many papers on the Hainan flora published.
1922	Fellow, American Academy of Arts and Sciences.
1923	Publication of *Enumeration of Philippine Flowering Plants* commenced.
1923	First important papers on phytogeography published.
1923	Member, National Academy of Sciences, Washington, D. C.
1923	Corresponding Member, Société des études océannes, Tahiti.
1923	Member, Second Pan-Pacific Science Congress at Melbourne and Sydney, Australia.
1924	*Bibliography of Polynesian Botany* issued.
1924	Correspondent, Muséum National d'Histoire Naturelle, Paris.
1924	Correspondent, Naturhistorisches Museum, Vienna.
1924	First paper on the Indo-China flora published.
1924	Council Member, Save-the-Redwoods League.
1924–29	Professor of Agriculture and Dean, College of Agriculture, University of California, and Director, Agriculture Experiment Station.
1925–29	Editor, *Hilgardia.*
1925	Member, Société Botanique de France, Paris.
1925	Corresponding Member, Deutsche Botanische Gesellschaft.
1925	Member, California Academy of Sciences.
1926	Sc. D., University of Maine.
1926	*Enumeration of Philippine Flowering Plants* finished.
1927	*Enumeration of Hainan Plants* published.
1927–28	Director, California Botanical Garden, Los Angeles.
1929	Corresponding Member, Peking Society of Natural History.

1930	Vice President and Chairman, Section of Nomenclature, Fifth International Botanical Congress, Cambridge, England.
1930	First important paper on ethnobotany issued.
1930–31	American editor of *International Address Book of Botanists.*
1930–35	Director, The New York Botanical Garden.
1930–35	Professor of Botany, Columbia University.
1931	Vice President and Chairman, Section G, American Association for the Advancement of Science; Acting President, A.A.A.S. Meeting, December 1931.
1931	Member, Latin American Committee of Selection, Guggenheim Foundation.
1931	*Brittonia* established. Editor, 1931–35.
1931–35	Trustee, Horticultural Society of New York.
1931	Member, New York Academy of Sciences.
1932	Member, Washington Academy of Sciences.
1932	Ehrenmitglied, Deutsche Botanische Gesellschaft.
1932	Member, American Philosophical Society.
1932	Member, Educational Advisory Board, Guggenheim Foundation.
1932	Correspondent, Academy of Natural Sciences of Philadelphia.
1933	Foreign Member, Linnean Society of London.
1933	Delegate, Fifth Pacific Science Congress, Victoria and Vancouver, representing the U. S. Government.
1934	President, Botanical Society of America.
1934	First paper on the Sumatra flora published.
1935	Member, Board of Managers, The New York Botanical Garden.
1935	President, International Union of Biological Sciences.
1935	Honorary Member, Netherlands Botanical Society.
1935	Honorary Member, Royal Horticultural Society of London.
1935	Honorary Member, Pennsylvania Horticultural Society.
1935	President, Section of Taxonomy and Nomenclature, Sixth International Botanical Congress, Amsterdam.
1935	Appointment to Arnold Professorship of Botany, Director of the Arnold Arboretum, and Administrator of Botanical Collections, Harvard University.
1935	Commentary on Loureiro's *Flora Cochinchinensis* published.
1935	Advisory Editor, *Chronica Botanica.*
1935	Official delegate to the Sixth International Botanical Congress, Amsterdam, Sept. 2–7, 1935, representing the United States Government, also National Academy of Sciences, The New York Botanical Garden, A.A.A.S., Bishop Museum, and the New York Academy of Sciences. Chairman of the U. S. Government and National Academy of Sciences delegations.
1936	President at Large, Herb Society of America.

1936	Honorary Member, Japanese Botanical Society.
1936	LL. D., University of California.
1936	Sc. D., Harvard University.
1936	Official guest of Harvard University at the Tercentenary Celebration.
1936	Member, Board of Managers, Barro Colorado Biological Station.
1937	President, New England Botanical Club.
1937	*Polynesian Botanical Bibliography (1773–1935)* published.
1937	Académico Honorario, Universidad Nacional de La Plata.
1938	Honorary Member, Kon. Nederlandsch Aardrijkskundig Genootschap.
1938	Trustee, Massachusetts Horticultural Society.
1938	*A Bibliography of Eastern Asiatic Botany* (with E. H. Walker) published.
1939	Recipient of the Linnean Gold Medal, Linnean Society of London.
1939	Médaille d'Or awarded by the Société Nationale d'Acclimatation.
1939	First of many papers on the flora of New Guinea and the Solomon Islands published.
1939	Corresponding Member, Institut Genevois.
1940	Associate, Muséum National d'Histoire Naturelle, Paris.
1940	President, Fairchild Tropical Garden, Florida.
1941	Honorary Member, Royal Agricultural and Horticultural Society of India.
1941	First paper on the flora of Burma published.
1941	*Arnoldia* established.
1942	Work on *Index Rafinesquianus* initiated.
1942	*Sargentia* established.
1942–45	Much work concerned with the identification of botanical material sent in by service men scattered from Upper Burma to New Caledonia. Lectured every two months to each incoming group of trainees in the intensive refresher course on tropical medicine, Army Medical School, Washington, D. C., on poisonous and emergency food plants.
1943	*Emergency Food Plants* published by the U. S. War Department.
1943–45	Consultant to the Secretary of War.
1944	Work on problems in nomenclature of Bartram, Amos Eaton, and Muhlenberg initiated.
1945	Recipient of Appreciation of Services as Consultant to the Secretary of War.
1945	Vice President, International Council of Scientific Unions.
1945	Correspondant, Académie des Sciences de l'Institut de France.
1945	*Plant Life of the Pacific World* published.
1945	Honorary Foreign Member, Edinburgh Botanical Society.

1946	Honorary Foreign Member, Kungl. Svenska Vetenskapsakademien.
1946	Member, Advisory Scientific Board, Gorgas Memorial Institute.
1946	Member, Board of Directors, Escuela Agrícola Panamericana.
1946	Honorary Fellow, Royal Society of Edinburgh.
1946	*A Botanical Bibliography of the Islands of the Pacific* published.
1946	Resignation as Director of the Arnold Arboretum accepted, effective July 31.
1946	Member, Administrative Board, Canal Zone Biological Area.
1946	Member, Pacific Science Council.
1946	Member, Executive Committee, Mass. Forest and Park Assn.
1946	Collaborator, Botanical Garden, Buitenzorg, Java.
1946–48	Arnold Professor of Botany.
1947	Recipient of the George Robert White medal of honor.
1948	Emeritus Professor of Botany.
1948	Commander, Netherlands Order of Oranje Nassau.
1948	Certificate of Appreciation, Federated Garden Clubs of Massachusetts.
1948	Member, Special Commission on Botanical Nomenclature, Utrecht, Holland.
1948	Honorary President, Botanical Section, International Union of Biological Sciences.
1948	President, Section of Nomenclature, Seventh International Botanical Congress, Stockholm. July 7–20.
1948	Grand médaille Geoffrey St. Hilaire, Société nationale d'acclimatation de France.
1949	Corresponding Member, Sociedad de Botanica Cubana.
1950	Vice President, Royal Horticultural Society, London, England.
1950	Honorary President, Plant Science Section, International Association of Biologists.
1951	Honorary Sc. D., 250th Commencement, Yale Univ.
1951	Guggenheim Fellow for work on Malaysian collection, British Museum (Nat. Hist.) July 3–Dec. 15, 1951. Renewed for a second year, 1952.
1951	Member, Board of Trustees, Flora Malesiana Foundation.
1952	Distinguished Service Award, The New York Botanical Garden.
1956	Died, Forest Hills, Mass., February 25.

KEY TO ABBREVIATIONS

Amer. Anthropol. = American Anthropologist
Amer. Fern Jour. = American Fern Journal
Amer. Jour. Bot. = American Journal of Botany
Amer. Nat. = American Naturalist
Amer. Orchid Soc. Bull. = American Orchid Society Bulletin
Amer. Scholar = American Scholar
Ann. Jard. bot. Buitenzorg = Annales du Jardin botanique de Buitenzorg
Arnold Arb. Bull. Pop. Inf. = Arnold Arboretum Bulletin of Popular Information
Bishop Mus. Occ. Pa. = Bishop Museum Occasional Papers
Bot. Gaz. = Botanical Gazette
Bot. Jahrb. = Botanische Jahrbücher
Bot. Mag. Tokyo = Botanical Magazine, Tokyo
Bot. Rev. = Botanical Review
Bull. Bishop Mus. = Bulletin of the Bishop Museum
Bull. Jard. bot. Buitenzorg = Bulletin, Jardin botanique de Buitenzorg
Bull. Soc. bot. France = Bulletin, Société botanique de France
Bull. Torrey Bot. Club = Bulletin of the Torrey Botanical Club
Bur. Sci. Monog. = Bureau of Science Monographs
Bur. Sci. Publ., Manila = Bureau of Science Publications, Manila
Chron. Bot. = Chronica Botanica
Contr. Gray Herb. = Contributions from the Gray Herbarium
Contr. U. S. Nat. Herb. = Contributions from the United States National Herbarium
Fedde Repert. = Fedde, Repertorium specierum Novarum regni vegetabeles
Gard. Bull. Straits Settl. = Garden Bulletin, Straits Settlement
Geog. Rev. = Geographical Review
Jour. Amer. Med. Assn. = Journal of the American Medical Association
Jour. Arn. Arb. = Journal of the Arnold Arboretum
Jour. Bot. = Journal of Botany
Jour. Malay Branch R. As. Soc. = Journal of the Malay Branch of the Royal Asiatic Society
Jour. N. Y. Bot. Gard. = Journal of The New York Botanical Garden
Jour. Roy. Hort. Soc. = Journal of the Royal Horticultural Society
Jour. Straits Branch R. As. Soc. = Journal of the Straits Branch of the Royal Asiatic Society
Jour. Urusvati Himal. Res. Inst. = Journal of Urusvati Himalayan Research Institute
Jour. Wash. Acad. Sci. = Journal of the Washington Academy of Sciences
Lingnan Agric. Rev. = Lingnan Agricultural Review
Lingnan Sci. Jour. = Lingnan Scientific Journal

Meded. Rijks. Herb. Leiden = Mededeelingen van Rijks Herbarium, Leiden
Mem. Amer. Acad. Arts Sci. = Memoirs of the American Academy of Arts and Sciences
Mem. Brooklyn Bot. Gard. = Memoirs of the Brooklyn Botanic Garden
Mem. Gray Herb. Harvard Univ. = Memoirs of the Gray Herbarium of Harvard University
Mid-Pacific Mag. = Mid-Pacific Magazine
Mitt. Inst. allgem. Bot. Hamburg = Mitteilungen aus dem Institut für allegemeine Botanik, Hamburg
Mo. Bull. Calif. State Dept. Agric. = Monthly Bulletin of the California State Department of Agriculture
Mo. Bull. Hort. Soc. N. Y. = Monthly Bulletin of the Horticultural Society of New York
Nat. Acad. Sci. Biogr. Mem. = National Academy of Sciences Biographical Memoirs
Nat. Hist. = Natural History
Not. Nat. = Notulae Naturae of the Academy of Natural Sciences of Philadelphia
Off. Reg. Harvard Univ. Reprint = Official Register of Harvard University Reprint
Pacific Sci. = Pacific Science
Pa. Mich. Acad. Sci. = Papers of the Michigan Academy of Science, Arts and Letters
P. I. Bur. Agric. Bull. = Philippine Island Bureau of Agriculture Bulletin
P. I. Bur. Forestry Bull. = Philippine Island Bureau of Forestry Bulletin
P. I. Dept. Agric. Bur. Sci. Pop. Bull. = Philippine Island Department of Agriculture Bureau of Science Popular Bulletin
Phil. Jour. Sci. = Philippine Journal of Science
Proc. Amer. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
Proc. Amer. Philos. Soc. = Proceedings of the American Philosophical Society
Proc. Linn. Soc. = Proceedings of the Linnaean Society
Proc. Linn. Soc. N. S. W. = Proceedings of the Linnaean Society of New South Wales
Proc. Pan-Pacific Sci. Congr. = Proceedings of the Pan-Pacific Scientific Congress
Proc. Roy. Can. Inst. = Proceedings of the Royal Canadian Institute
Proc. Roy. Soc. Queensland = Proceedings of the Royal Society of Queensland
Rept. Phil. Comm. = Report of the Philippine Commission
Rev. Argent. Agron. = Revista Argentina de Agronomía
Rev. Inter. Bot. Appl. Agr. Trop. = Revue Internationale de Botanique Appliquée et d'Agriculture Tropicale

Rev. of Rev. = Review of Reviews
Rev. Sudam. Bot. = Revista Sudamericana de Botánica
Sarawak Mus. Jour. = Sarawak Museum Journal
Sci. Mo. = Scientific Monthly
Trans. Amer. Philos. Soc. = Transactions of the American Philosophical Society
Trans. Nat. Hist. Soc. Formosa = Transactions of the Natural History Society of Formosa
U. S. Dept. Agric. Bur. Pl. Ind. = United States Department of Agriculture Bureau of Plant Industry
U. S. Dept. Agric. Div. Agrost. = United States Department of Agriculture Division of Agrostology
Univ. Calif. Publ. Bot. = University of California Publications on Botany
Yearb. Amer. Philos. Soc. = Yearbook of the American Philosophical Society

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(*Prepared with the assistance of Lazella Schwarten*)

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February 15, 1829—January 4, 1914

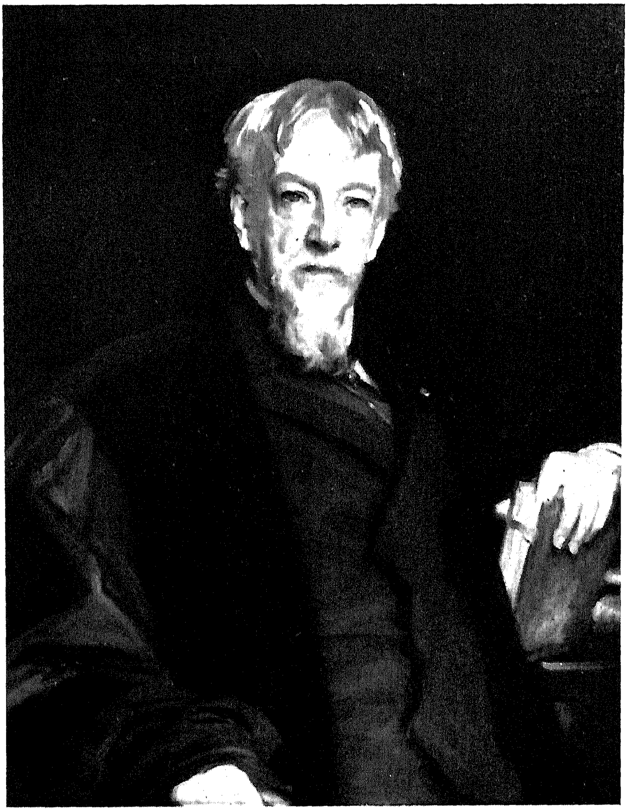
BY PERCIVAL BAILEY

SILAS WEIR MITCHELL was born in Philadelphia on February 15, 1829. His father, John Kearsley Mitchell, was the son of a Scotch immigrant and his mother, Sarah Matilda Henry, was the daughter of a prosperous merchant with wealthy relatives in England who were later of great assistance to the family.

John Kearsley Mitchell was a physician with a successful practice and, as was customary in those days, if one wanted to be considered a leader in the profession, taught chemistry in the Philadelphia Medical Institute. He made some creditable contributions to osmosis and to the liquification and solidification of carbonic acid, and wrote an original dissertation on the neurotic spinal atrophies. He wrote poetry, some of which was praised by Edgar Allan Poe, and was much addicted to literary societies. He was also very fond of the out of doors. A cheerful, sociable person, he was universally liked. He drove himself unmercifully at his varied interests; his health failed early, and he died in 1858, just as Weir was trying to establish himself in practice.

Weir was the third of nine children, a noisy turbulent crew, who entered into all the activities of their father and became easily accustomed to the distinguished guests who frequented their home. They were very fond of their father, who could still their noise with a word.

A lanky, lackadaisical boy, dreamy and, later, diffident, Weir was usually to be found lying on his stomach reading anything that came



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into his hands, but mostly fiction. His mother finally burned the *Arabian Nights* from despair that he would ever study as long as he could gain access to it. He was usually in trouble at the various schools which he attended. The masters in those days were rather brutal, and Weir tells how, years afterward, he could never meet one of them without terror. This life continued until he was sixteen, when he began to spit blood. His father then purchased a boat for him and encouraged him to spend more time out of doors.

Weir was slow in deciding on a vocation. His father suggested that he enter the mercantile life. His mother's cousin, a merchant in Manchester, England, proposed to take him into his firm and make him his heir, but died before the plan could be carried out. At last Weir decided to be a doctor, much to the disgust of his father, who remarked that he had brains enough but no industry. The outlook was not bright. After he had acquired the boat, he used to lie in it for hours, dreaming and writing poetry and tales.

Having made up his mind, he entered Jefferson Medical College. It was very hard for him, since he had not learned to study. He used to fall asleep over the bones and had to drink much strong coffee in order to keep awake. Moreover, he loathed blood and fainted repeatedly at operations. He fell severely ill of jaundice and it was four years before he completed his medical studies, in 1850.

Meanwhile, the only subject which had interested him was physiology. He made up his mind to obtain a chair in one of the medical schools. Always rather smug and self-satisfied, he found it a great blow when he failed to obtain the post he coveted, in spite of his abilities, accomplishments, and undoubted political skill.

Although his father's health was failing, it was possible for Weir, with financial assistance from his mother's cousin, to go abroad for further study. After a brief stay in London he went on to Paris, then the Mecca of American physicians. Here he came under the spell of Claude Bernard, who made a remark which greatly influenced his later career. Weir had said that he thought something must be so.

"Why think," replied Bernard, "when you can experiment? Exhaust experiment and then think."

As soon as he entered the wards of the hospital, he caught smallpox and was very ill. His older sister Elizabeth came to Paris and took him on a trip to Italy to recuperate. His request to resume his interrupted studies in Paris was refused because of his father's decline in health, and he was obliged to return home and help his father with his practice. Although his father wanted him to become a surgeon, and Weir had taken courses in that subject in Paris, he found it distasteful and turned to internal medicine. He wanted to become an interne at the Pennsylvania Hospital, but was never accepted because his father had some dispute with the Trustees. He did some teaching, but was a poor lecturer. He applied for the chair of physiology at Jefferson, but failed to obtain it.

His talents and interests had been turned by Bernard toward experimentation, his principal interests being in the field of toxicology. When lecturing in the summer school on animal poisons, he had been intrigued by a remark of one of his auditors, W. A. Hammond, later Surgeon General of the Army, concerning an antidote for snake bite which he had heard of in Texas. While he was turning this over in his mind, a man came to his door with some rattlesnakes which he wished to sell. He immediately launched, with the assistance of Hammond and the advice of Edward T. Reichert, Professor of Physiology in the University of Pennsylvania, upon a long experimental study of snake venom, which taxed his strength and resources to their limits, since heavy family burdens had fallen onto his shoulders at the death of his father after a series of strokes. Their combined practice dropped off to a third of its former volume and picked up slowly. Fortunately, his English relatives came to his aid again and made a substantial allowance to the family for several years. This allowed him to marry Mary Middleton Elwyn, but for many years the burden which he carried was very heavy. Nevertheless, he tenaciously carried on his experimental studies, in spite of the advice of his colleagues that a reputation as a scientist would harm his practice.

Busy with his experiments, his teaching, his practice, and his family responsibilities, the years passed by until 1862. His reputation grew. He was made an honorary corresponding member of the British Medical Society. His researches on the venom of the rattlesnake attracted much attention abroad, and Oliver Wendell Holmes sent him a copy of *Elsie Venner* with the remark that it might interest him because it was a little bit rattlesnaky. His responsibilities had sobered him; he got his irascible temper under control; he developed an affability tempered by a certain austerity. He made many friends—Hammond, Billings, Keen, Da Costa, Phillips Brooks—and his life had begun to run in the smooth groove of a successful practitioner when John Brown's Raid led him into an experience which was to color his entire subsequent existence. About this time his wife died of diphtheria and, although his mother and his sister Elizabeth took over the care of his family, he was very lonely and plunged desperately into the work of the army.

Because of his heavy family responsibilities, he did not become a surgeon with the army, but took charge of the Turner's Lane Military Hospital near Philadelphia in which, because of his interest, the Surgeon General concentrated all of the injuries of nerves. These cases Weir studied assiduously with W. W. Keen and Morehouse. Together with his growing practice, these clinical responsibilities took all his time and energy. His experimental studies ceased, but he interested a young Japanese physician named Noguchi in them and continued to devote interest and financial support to the study of animal poisons.

The results of this study of wounds of the peripheral nerves were embodied in a monograph written with Keen and Morehouse, which remained the classic on the subject until the First World War. Mitchell wrote many other articles and pamphlets of permanent value on his experiences with lesions of the nervous system, of which might be mentioned his description of a painful syndrome which he named causalgia. These studies permanently altered the nature of his medical practice. He became a consultant in nervous diseases, the most eminent and probably the greatest that this country has produced. In the postwar period his reputation became world-wide; he was made an honorary or corresponding member of many foreign societies. He was happy with the respect of his colleagues and friends until, in 1872, his mother died, followed two years later by his sister Elizabeth. He could not tolerate the loneliness. In 1875 he married Mary Cadwalader. She proved a perfect helpmate, and their daughter added the patter of little feet to his household.

As his practice grew, he had a great number of patients who suffered from "nerves" but had no organic lesions of their nervous systems. In the rapid expansion of the economy following the war, many patients, especially women, found themselves with much money, but without the talents to find occupations for themselves. Mitchell became very much interested in them and in what might be done for them.

This led him into two lines of endeavor: serious scientific studies of neurotic patients, and literary portrayals of their characters. From boyhood he had been, like his father, interested in writing but, except for anonymous poetry, had held this desire in check, on the advice of his friends that a reputation as a writer would injure his practice. Now he felt sufficiently secure to indulge openly in this passion. The result was a series of seventeen novels which, whatever their merit as literature, contain vivid pictures of pathological characters. One of them, *Hugh Wynne, Free Quaker,* has for long been considered the most accurate picture ever written of Philadelphia at the time of the Revolution, and is standard reading in American literature courses. Its historical accuracy has been abundantly proven.

For the understanding of neurotic patients, Weir Mitchell had serious handicaps. He was a patrician, with all the prejudices and inhibitions of that status in a Quaker environment. His studies give the impression today of being quite superficial. However, for their time they were useful. His rest cure became very popular throughout the world and his books *Wear and Tear* and *Fat and Blood* went through many editions. His main contribution, perhaps, was to persuade physicians to give up treating these conditions with drugs. He demonstrated that better results could be obtained by nonmedicinal treatments, such as rest, isolation, overfeeding, and massage. Of course, he was accused of being a charlatan, especially since his practice increased by leaps and bounds.

In spite of criticism, Mitchell continued upon his way. His prestige, coupled with a certain arrogance and lack of humor, enabled him to get many things done which were to the advantage of medicine. He tangled with the Catholic Church, but was able to force the sisters to wear suitable dress in the operating room. He harassed his colleagues until he got a new building for the College of Physicians. He was instrumental in establishing the Franklin Club. He served for many years as a trustee of the University of Pennsylvania.

His literary pursuits brought him many friends—notably Oliver Wendell Holmes, James Russell Lowell, and William Osler. He was given honorary degrees by Harvard, Edinburgh, Princeton, and Toronto. He was commissioned to represent the Smithsonian Institution and the National Academy of Sciences (to which he had been elected in 1865) at the Eight Hundredth Anniversary of the University of Bologna. His summers he spent at Little Boar's Head on the Maine coast, with frequent fishing forays farther afield. Secure in his fame, his practice, his family, and his friends, he reached nearly the end of the nineteenth century when, in 1898, fate struck him a heavy blow. His daughter died of the same disease which had taken his first wife.

Mitchell continued to work, to write, and to live much as before, but the zest of life was gone. He became somewhat irritable, dictatorial, and dogmatic. His trials were increased in 1906 when a large trust company, of which he was a director, failed. To repair the damage he pledged a large part of his fortune. He was much encouraged during this period by the faithfulness of his friends. Also, his son, an able physician, remained by his side, refusing the offers of responsible positions elsewhere. Mitchell's eightieth birthday was happily celebrated. More honors were showered upon him and then, swiftly, came the end. He fell ill of influenza and died on January 4, 1914.

Knowing how deeply the tragedy of the Civil War had affected him, one can only rejoice that he was spared the agony of the First World War. With him passed a gracious epoch in the history of our country, of which he is a principal ornament.

KEY TO ABBREVIATIONS

Am. J. M. Sc. = American Journal of the Medical Sciences
Am. J. Nursing = American Journal of Nursing
Am. Med. = American Medicine
Arch. Scient. & Pract. Med. = Archives of Scientific and Practical Medicine
Atlan. = Atlantic Monthly
Boston M. & S. J. = Boston Medical and Surgical Journal
Brain = Brain, a Journal of Neurology
Brit. M. J. = British Medical Journal
Bull. M. & Chir. Fac. Maryland = Bulletin of the Medical and Chirurgical Faculty of Maryland
Cent. = Century Magazine
Charleston M. J. & Rev. = Charleston Medical Journal and Review
Chicago M. Rev. = Chicago Medical Review
Internat. Clin. = International Clinics
J. A. M. A. = Journal of the American Medical Association
J. Nerv. & Ment. Dis. = Journal of Nervous and Mental Disease
Lipp. Mag. = Lippincott's Magazine
M. & S. Rep. = Medical and Surgical Reporter
M. News = Medical News
M. News & Abstr. = Medical News and Abstract
M. Rec. = Medical Record
Med. Contemp. = A Medicina Contemporânea (Lisbon)
New York M. J. = New York Medical Journal
No. Am. M. Chir. Rev. = North American Medico-Chirurgical Review
Philadelphia M. J. = Philadelphia Medical Journal
Philadelphia M. Times = Philadelphia Medical Times
Proc. Biol. Dept. Acad. Natur. Sc. = Proceedings of the Biological Department of the Academy of Natural Sciences
Therap. Gaz. = Therapeutic Gazette
Tr. A. Am. Physicians = Transactions of the Association of American Physicians
Tr. Am. Neurol. A. = Transactions of the American Neurological Association
Tr. Coll. Physicians Philadelphia = Transactions of the College of Physicians of Philadelphia
Tr. M. & Chir. Fac. Maryland = Transactions of the Medical and Chirurgical Faculty of Maryland
Univ. M. Mag. = University Medical Magazine

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HENRY NORRIS RUSSELL

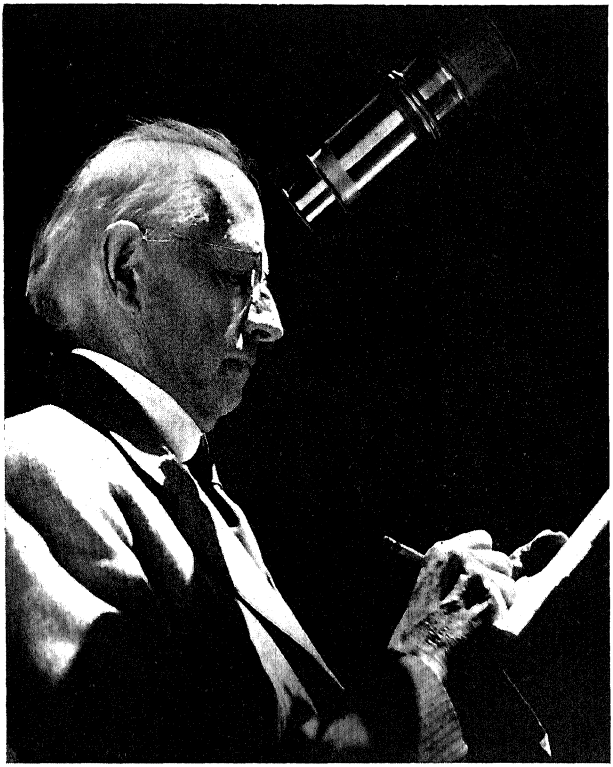
October 25, 1877—February 18, 1957

BY HARLOW SHAPLEY

HENRY NORRIS RUSSELL was born on October 25, 1877, in Oyster Bay, New York, the son of a Presbyterian minister. His education was acquired principally at home until the age of twelve, and then at the Princeton Preparatory School and Princeton University; from the latter he was graduated in 1897 with the highest standing ever attained by a Princeton undergraduate. Throughout all of his mature life, as a member of the Princeton faculty, he lived at 79 Alexander Street, but spent many summers on the New England coast or in travel.

Russell was awarded in due course all the formal distinctions that America's leading astronomer merited. He was made a foreign associate of the Royal Societies of London, Edinburgh, and Belgium; Correspondent of the French Academy of Sciences, and Associate of the Royal Astronomical Society of London. His honorary degrees came from Dartmouth, Louvain, Harvard, Chicago, Michoacan (Mexico); his medals and prizes from the Royal Astronomical Society of London, the French Academy (Lalande and Janssen), National Academy of Sciences (Draper), Astronomical Society of the Pacific (Bruce), American Academy of Arts and Sciences (Rumford), Franklin Institute (Franklin), and the American Philosophical Society (John L. Lewis prize). He was the first Henry Norris Russell Lecturer of the American Astronomical Society.

In Russell's brief autobiographical statement for the National



Henry Norris Russell

Academy of Sciences two paragraphs report on his natural interest in mathematics and on his early education:

"It may be relevant to record that a strong interest in mathematics appears to 'run in the family.' My maternal grandmother won a mathematical prize on her graduation in 1840 from Rutgers Female Institute in New York (the first institution in that city for the higher education of women). My mother was easily first in a 'ladies class' in mathematics given by professors of the University of Edinburgh about 1868. I was awarded a fellowship in mathematics on my graduation from Princeton. My children, though none of them have followed careers in the mathematical sciences, have all enjoyed their courses in mathematics and done well in them with no great effort.

"I was always interested in astronomy. (I recall my parents showing me the transit of Venus in 1882, when I was five years old.) Specialized interest in it was aroused mainly by C. A. Young of Princeton—a great teacher as well as a great astronomer. My first independent contribution dealt with the atmosphere of Venus."

My address to the American Astronomical Society in May, 1957, on Russell's scientific work follows:

In Colonel Stratton's obituary of Henry Norris Russell in *Nature* for March 16, 1957, appears this concluding evaluation: "A man of overflowing energy, never sparing himself in his own work or in assisting the researches of others, he was the most eminent and versatile theoretical astrophysicist in the United States if not in the world."

When I cast back in my memory (before I examine the full bibliography), I pick out the following as Russell's most outstanding contributions:

1. The color magnitude diagram.
2. Eclipsing binary theory and calculations.
3. Spectrum analysis, laboratory and stellar.
4. The masses of stars, including analysis of visual double stars.
5. Popularization of astronomy at a high level.

This last refers to the famous textbook with Dugan and Stewart, to some general lectures, and especially to the monthly contribution, over forty years, to the *Scientific American*—a survey of astronomical problems and progress much like the current series by Otto Struve in *Sky and Telescope.*

In the foregoing five fields Russell did indeed do outstanding work, but picking up the list of about 200 technical papers, I see that I have left out at least five fields that should not have been overlooked:

6. Solar and stellar composition and constitution (for example, the "Russell mixture" so much used in cooking up atmospheric models).
7. The origin of the planets and comets.
8. Characteristics of planetary atmospheres.
9. The contacts of religion with science, and vice versa—and
10. Perhaps the most important of all, general consulting on all astronomical and spectroscopic problems.

Colonel Stratton is right about the unequaled versatility of Russell, who has written modestly of himself that as a boy he was rather acutely studious, "somewhat preferring mathematical studies, and with *no marked scholastic dislikes.*" Going much further, all of us would agree that the word *genius* more rightly applies to him than to any other American astronomer of these or earlier times. And as a genius he was at times pretty hard going for many of us followers who think and talk slowly and raggedly. As one of his first graduate students I quickly learned to use monosyllables—"Yes, No, Yes? So? How's that?" and "Ummmm." That drawling monosyllable "Ummmm" conceals more careful ignorance than any other in the Queen's English. I doubt if I fooled him. We would walk on the Princeton campus, he waving his cane to shoo the inconsequential students off the walks—he calculating and scintillating—I listening, guessing, wondering, trying to de-confuse myself. You may remember that I claim to be the original Russell Mixture.

Of the ten major fields of Russell's interest and activity, I shall choose only three or four for comment. First the happy assignment and acceptance of being America's wide-ranging astronomical consultant.

Beginning in the early 1920s Russell was officially a visiting research associate at the Mount Wilson Observatory. When I was shipped East to Harvard, so the rumor goes, they were happy that the released dollars (there were not very many, I assure you) permitted the bringing of Russell to Pasadena. It was indeed a clever bargain arranged by Mr. Hale.

From Russell's long association with Mount Wilson came many scientific contributions—largely spectroscopic. Some were inspired by his association with Walter S. Adams, A. S. King, and H. D. Babcock. Later he was made an official research associate of the Harvard Observatory. And he also regularly visited the Lick and Lowell Observatories, the National Bureau of Standards, and other research groups. One year he was Morrison Research Associate on Mount Hamilton. The assistance he gave everywhere was immense—criticisms, hunches, and much computational labor. He liked to mess around with numbers.

In the few paragraphs that he has written about himself for the records of the National Academy of Sciences, he says, "I have always enjoyed detailed numerical work," and such computational work has been used freely in all his investigations. Professor Dugan once remarked, "Russell will spend much more time hunting for ingenious short cuts than would be required to take the long cut."

Russell's informal role over three decades as National Astronomical Consultant was supplemented formally by joint authorships of scientific publications. His first collaborator was Arthur R. Hinks at Cambridge, England, where, in his early post-doctorate days, he measured trigonometric parallaxes of stars without too much success.

In 1912 began our joint work on the orbital theory and practice of eclipsing binary stars; and at the same time began the collaboration of Harvard, Yale, and Princeton on the positions of the moon determined photographically. "Harvard makes photographs, Princeton makes measures, and Yale thinks" was alleged to be the arrangement. The collaborators were E. C. Pickering, E. W. Brown, Russell, and a philanthropist (George Russell Agassiz) who paid for the many girl-hours.

I have made a list of subsequent joint authorships—about twenty-five in number. Here are some of the names: Adams, Joy, Stewart, Saunders, Dugan, Karl Compton, Boyce, Menzel, Bowen, Shenstone, Meggers, Arthur King, Robert King, Mrs. Gaposchkin, and, most frequently collaborating, Charlotte Moore (Sitterly). Many other contributions could well have carried his name as joint author, but such credits did not interest Russell. He was casual about credits to himself, but intense about anybody's scientific discoveries.

While still a Princeton graduate student, Russell published two papers that pointed directly to two of his future life-long interests. The first was "The Atmosphere of Venus," published in 1899 in the then young *Astrophysical Journal*. It makes good reading today; it shows a distinct maturity. Later that year appeared his paper "The Densities of Variable Stars of the Algol Type." Many of his subsequent papers deal with eclipsing stars, and also a large number with planetary atmospheres.

Other early scientific papers (1897–1900) touched celestial mechanics, e.g., "The Great Inequality of Eros and the Earth." That was the time of considerable excitement over the highly eccentric orbit of the newly discovered asteroid. Russell's last published paper, by the way, was encouraged by Mrs. Nail and me a couple of years ago. We tempted him, after he had thought his effective work was completed, by sending him light curves of some eclipsing stars in the Magellanic Clouds. (It is well, we argued, to be sure that the gravitational laws are the same in those mixed up galaxies as in our own; it is important also to see if the stars are similar in general respects.) Russell's contribution (this last one) was printed, just a week before his death, in the second volume of Dr. Beer's *Vistas*.

Most of Russell's last decade of work dealt with eclipsing star orbital theory. He devoted much time to the work of J. E. Merrill and Z. Kopal.

Beginning in the middle of the 1920s he turned his guns on the mysteries of radiation. He devoted more of his time to spectrum analysis, a subject on which he has left an indelible impression. With Saunders, Charlotte Moore Sitterly, Meggers, Lang, Bowen, and others, he brought order out of chaos among the arc and spark spectra of the elements.

From 1925 to 1930 his activity produced twenty papers on line spectra. Some of them were classics, such as "A Calibration of Rowland's Scale of Intensities for Solar Lines," "The Arc and Spark Spectra of Titanium" (130 pages in the *Astrophysical Journal*), and, with F. A. Saunders, "The Spectrum of Ionized Calcium." This last introduced the famous Russell-Saunders coupling in complex spectra.

That interval of five years yielded also the Russell-Dugan-Stewart two-volume textbook, which reoriented and essentially revolutionized astronomical teaching and astronomical textbook writing in America. Also at that time he gave the Terry lectures at Yale which resulted in the book *Fate and Freedom*. In this same pentad of activity appeared (with Mrs. Sitterly as joint author) the important catalogue of the dynamical parallaxes of 1,777 double stars.

The 1930s were also furiously active and scientifically enjoyable—the work being more spectroscopic than astronomical. Much more could be said of Russell's work on laboratory and stellar spectra, but I should devote a little time to some miscellaneous half-forgotten enterprises.

There was the tricky analysis in 1921 of radioactive data which led to his fixing the upper limit to the age of the earth's crust. He starts with the observation that if the whole crust had been originally composed of uranium it would have decayed to the present terrestrial abundance in 17 half-periods, or 8.5×10^{10} years. "But this assumption," he remarked, "would lead to the absurd conclusion that the crust must now be composed entirely of the products of the radioactive disintegration of the original uranium." He considers the lead situation, and the contribution of thorium, and eventually concludes, "indeed it might be safe to say that the age of the crust is between two and eight thousand millions of years." That was thirty-five years ago, and much has since been done in age measurement by techniques then unknown. But he had it right. Now we would probably say between four and six thousand million years.

The Terry lectures in Yale in 1927 resulted as remarked above in the small book *Fate and Freedom*. The three chapters are: "Fate and Freedom," "God and Man," "Body and Soul." I recommend the book to those of you who are wondering about human fate, as doomed by the stars and solaced by the comforts of religion.

On page 132 of *Fate and Freedom* I find a rather satisfactory personal definition of that evasive concept "soul." Russell says: "By soul I mean here the personality, the conscious individual who understands, feels, remembers, responds to us." Soul equals personality. I rather like that. But Russell states, "When the body dies the soul vanishes utterly." I do not agree with that view. He is inconsistent. I always intended to point out to him the obvious error. For the personality (therefore soul) survives. His personality, in a sense, is here at the present time and will continue to survive. But he and I didn't get to argue such things—eclipsing stars and the iron multiplets always got in the way. Perhaps it is just as well.

Russell's proper field of science was astronomy and spectroscopy, but on the side he was interested in poetry, geology, archaeology, botany, and travel. He knew the Princeton countryside and the deserts of the Southwest; he knew the North Cape and the Nile Valley with its monuments.

In those early Princeton days, I, as an uncouth Missourian, was accepted with some reservations, but gradually I improved, and at last became aware of my arrival when Russell very privately told me a deep secret; that is, he told me just where in the woods four miles north of Princeton I could find the rare and precious fringed gentian. I had indeed made good!

To report a little further on his miscellaneous scholarly interests, I note in the bibliography the following: "Determinism and Responsibility," "A Planetary Date for Chaucer's Troilus," "The Borders of the Humanities." During the First World War there appeared a paper "On the Navigation of Airplanes."

Of more professional concern were the following contributions: "Dark Nebulae," "On Majorana's Theory of Gravitation," "Model Stars," "On the Origin of Periodic Comets," "The Probable Diameter of Stars," "The Solar Spectrum and the Earth's Crust," "The Masses of the Stars" (an important monograph), and the highly useful "List of Ultimate and Penultimate Lines of Astrophysical Interest." We do not have space here to explore these contributions, but conclude by coming back to the planets, where Russell began his scientific thinking.

His book entitled *The Solar System and Its Origin* has been a guide and inspiration to the many recent workers in this important field. Research and speculations have gone far since Russell's University of Virginia lectures. Later contributions have come from Alfven, ter Haar, Kuiper, Lyttleton, Urey, von Weizsaecker, Whipple, and others, but Russell's contribution of more than twenty years ago was distinctly the guiding pioneer work, both as a survey of the then current thought and as a rich source of suggestion.

In restrospect we note that Russell never seemed to interest himself in Milky Way structure, or in the many problems of the star clusters and galaxies, possibly because I talked too fast about them and he had little chance to contribute. Also he did not get deeply into the field of meteors. But he appeared to cover about all other astronomical fields in lively interest and many of them in original research. And he enjoyed his researches immensely, especially those where he must calculate the consequences of this and that. One of my clearest pictures of him shows his eager thoughtful gaze at the ceiling, or the horizon, with a 10-inch slide rule in his hands. He carried the logarithm tables in his phenomenal memory.

A few weeks ago I stood alone, with bared head, in the front yard at 79 Alexander Street, when his body was taken into the study from which I had so often come out inspired and determined; and I thought: "His interval out of infinite time is nobly concluded; it is now our continuing responsibility to pay interest on the investment he made in us."

KEY TO ABBREVIATIONS

A. J. = Astronomical Journal
Annals, H. C. O. = Annals of Harvard College Observatory
Annals, N. Y. Acad. Sci. = Annals of the New York Academy of Sciences
Ap. J. = Astrophysical Journal
B. A. A. J. = British Astronomical Association Journal
Bull. Amer. Math. Soc. = Bulletin of the American Mathematical Society
Carnegie Inst. Wash. Publ. = Carnegie Institute of Washington Publications
H. C. O. Bull. = Harvard College Observatory Bulletin
H. C. O. Circ. = Circulars of the Harvard College Observatory
Harv. Reprint = Reprints from the Harvard College Observatory
Helwan Publ. = Publications of the Helwan Observatory
J. Franklin Inst. = Journal of the Franklin Institute
J. Opt. Soc. Amer. = Journal of the Optical Society of America
J. R. A. S. Can. = Journal of the Royal Astronomical Society of Canada
J. Res. Nat. Bur. St. = Journal of Research of the National Bureau of Standards
Lick Obs. Cont. = Contributions from Lick Observatory
M. N. = Monthly Notices of the Royal Astronomical Society
Mt. Wilson Cont. = Mount Wilson Contributions
N. R. C. Bull. = National Research Council Bulletin
Nat. Hist. = Natural History
Obs. = Observatory
P. A. = Popular Astronomy
P. A. S. P. = Publications of the Astronomical Society of the Pacific
P. U. Obs. Cont. = Princeton University Observatory Contributions
Phys. Rev. = Physical Review
Pr. Alumni Weekly = Princeton Alumni Weekly
Pr. Univ. Bull = Princeton University Bulletin
Proc. Amer. Phil. Soc. = Proceedings of the American Philosophical Society.
Proc. N. A. S. = Proceedings of the National Academy of Sciences
Proc. R. Soc. = Proceedings of the Royal Society of London
Publ. A. A. S. = Publications of the American Astronomical Society
Publ. Modern Lang. Assn. Amer. = Publications of the Modern Language Association of America
Sci. Am. = Scientific American
Sci. Mo. = Scientific Monthly
Sci. Pa. B. S. = Scientific Papers of the Bureau of Standards
Tech. Rev. = Technology Review
Trans. Amer. Phil. Soc. = Transactions of the American Philosophical Society
Trans. I. A. U. = Transactions of the International Astronomical Union

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G W Stewart

GEORGE W. STEWART

February 22, 1876—August 16, 1956

BY HARVEY FLETCHER

GEORGE W. STEWART was born in St. Louis, Missouri, February 22, 1876, and died in Iowa City, Iowa, August 16, 1956, being in his eighty-first year. He was a member of the National Academy of Sciences for eighteen years and actively participated in its affairs during this period. He was at the State University of Iowa for forty-seven years, until his death.

His early childhood environment and training are very beautifully portrayed in the sketch which he sent to the Academy, from which I quote:

"I had an older brother, Oscar, an older sister, Mary, and a younger brother, Victor. The home life with four children was always an active one, especially since much of it was spent in a parsonage where there were always many callers. The interest of the home was largely centered in the community, in the needs of people generally and in the growth and influence of the local church. The making of money and attainment in life as measured by business success were naturally not often the subject of table or family discussion, chiefly because they were crowded out. There were no revolutionary views of society taught but rather the faith that society must be evolved through the individual's interest and endeavor to bring about a better civilization. The reading of good literature was emphasized, though most of this was upon problems of society.

There was little, if any, very light reading material in the home. Even standard works of fiction took second place.

"There was always emphasized the need for a sharp discrimination between right and wrong in conduct. But all this was suffused with the broadest type of interest in humanity and the greatest sympathy with the other fellow. For example, it was upon this ground that teetotalism was taught and practiced and that form of risk called gambling was avoided. Thus discriminations were based not only upon logic, but also importantly upon their practicability and their helpfulness to others.

"The home was not highly emotional religiously. Father became a minister because of the influence religion had upon people and the happiness in their homes. He was spiritually and not literally minded. His sermons were carefully and logically organized according to the custom of the day. Later in life he read more fiction, threw away all of his old sermons and based his shorter efforts on life as he saw it about him. Evidently he early regarded experimental religion as more to be stressed than theological beliefs or rigid creeds. It was the life he lived and the motives which actuated him that influenced all his children. His breadth of view was shown, as subsequently learned, by his setting aside the rules of the Methodist Discipline and receiving into the church *without baptism* those of the Quaker faith who did not approve of that ritual. This occurred at Carthage, Mo., in 1871–73, at a time when debate concerning forms of baptism were common, and many thought 'salvation' depended upon baptism. Also there subsequently came to light other acts which showed his view that all organization and rituals are but tools for the encouragement and enrichment of what he termed the spiritual life.

"Mother was ever watchful of the many possible errors that can be made by a pastor and had an abundance of good judgment that was exceedingly helpful to father. She was not a great reader, but a home maker and a leader of the women of the parish in the development of their activities. She seemed to know everything about her children at all times. She had an uncanny insight into the character of everyone she knew, and this was very helpful to father who was more trusting than she. There seemed to be present in the home a confidence in humanity, and yet an awareness of its weaknesses.

"The home was as harmonious as a character-forming one could possibly look to a child. Father and mother seemed to work together especially well because they seemed to have a common objective and did not overemphasize their own personal interests. There was no effort made in the home to determine the careers of any of the children. No particular professions or occupations were held up as ideal. We were led to look forward to higher education, if the finances would permit, and we were encouraged to have self-confidence. For why should not high thinking, earnest people succeed in rendering a service to civilization and thus have a place in the world? Often we were reminded that high thinking and simple living make men and women of real worth.

"My first recollections are of pleasant times, play with other children, entertainments in the church, social gatherings at the parsonage. The unpleasant recollections are only of cuts and bruises and minor accidents for which presumably I alone was responsible.

"I recall an early ambition that was never realized. It seems that I passed rather rapidly through the first room or two in school and that this gave me a confidence that I would soon pass through the rest of them. But the family only smiled indulgently at this ambition which I failed to achieve.

"One incident in the life of my older brother left a very marked impression. It appears that he rebelled at learning the multiplication tables, even inferring that he could not master it. My father summoned my brother to his study, informed him that there were no stupid ones in this family and suggested very definitely that my brother learn his tables forthwith or be punished. My brother learned the multiplication tables at once and was, from that time on, excellent in mathematics. He is O. M. Stewart, well-known textbook author in physics and for many years head of the Department of Physics, University of Missouri. This incident and its suggestiveness I have never forgotten.

"I was never bookish, preferring to play rather than to study. Not until the seventh or eighth grade did anything occur to stimulate me to serious efforts. Then my teacher in a very personal way appealed to my pride, telling me how much better my sister was than I. From that time on my studies became a more important challenge to my efforts.

"My first year of public school was at Sedalia, Mo. I continued at Carthage, Mo., from about six years to nine years of age; then at Kansas City, Mo., from nine until seventeen, completing three years of high school. The moves from Sedalia to Carthage and to Kansas City were made in March, the time of changes in the Methodist Conference to which father belonged. Undoubtedly these changes had some advantages, but also the disadvantage arising from the dissimilarity in the programs of the schools. I do not recall disliking any subjects in school.

"My home occupations during the school period were those of a city boy living in a semi-modern house. There were a few duties, but my school work was regarded as of first importance. During my second year in high school I studied shorthand in order better to be prepared to earn money during vacations. During the following summer I continued my stenographic training by working in a wholesale lumber office at a small wage. This employment continued for three hours per day through a large part of the last year in high school. Immediately following this I took a position at the Methodist Book Concern in St. Louis, Mo., where I spent a year and a summer laying aside funds to pay my way to college. This break in my education was a financial necessity.

"I entered DePauw University in September, 1893 and received Phi Beta Kappa and A. B. degree in 1898.

"I ran a boarding club a part of the time and earned money during summer vacations. I was able to graduate without interruptions and only a few hundred dollars in debt. I was honored by appointment to a responsible office by my college fraternity. I took a great interest in the fraternity, and this brought me into intimate contact with fifty or sixty men during the four years. In this way I acquired great faith in men. Also I saw and learned to appreciate almost, if not all, the human traits I have since known. This experience was important in making me at home in the world among those of different views.

"I borrowed the money for graduate study from a Mr. Kauffman of St. Louis and entered Cornell University in 1898. Received the degree of Ph. D. in 1901. Graduate assistant in physics, Cornell, 1899–1901. Elected to Sigma Xi in 1900."

He was an instructor at Cornell from 1901 to 1903, when he accepted a position at the University of North Dakota, where he stayed for six years. In 1909, he went to the State University of Iowa as Professor and Head of the Department of Physics and remained there until his death in 1956. During this period he served as Acting Dean of the Graduate School for several short periods.

He was a member of Phi Beta Kappa and an honorary member of Sigma Pi Sigma and Phi Kappa Phi. He was President of the American Physical Society in 1942 and a member of its Council for several years. In 1930 he became National President of the Society of Sigma Xi. He was awarded three honorary Doctor of Science degrees, by DePauw University (1928), University of Pittsburgh (1931), and Kalamazoo College (1949). The American Association of Physics Teachers awarded him the Oersted Medal for outstanding teaching in 1942. He was also identified with the Acoustical Society of America, The Optical Society of America, and the Society for Promotion of Engineering Education.

The physics building at the State University of Iowa is a monument to his name. Provost Harvey H. Davis of this University paid tribute to him in these words:

"He has given a long record of distinguished and devoted service to the University, both through his own efforts and through those of people he selected for staff appointments. The Physics Building was planned and its construction almost literally supervised by Dr. Stewart. Its long usefulness with comparatively little remodeling attests the wisdom of his planning."

Again I quote from his autobiography:

"It is difficult to know precisely how my later interests in life developed. They have never been separated from that early interest in people that was in the home as a child. Above has been related my stimulus to better study that occurred in the grade school. Fortunately though not at all bookish, I began to regard the assignments of study as something to conquer. I was made to think of education as a strengthening of the mental sinews rather than as an accumulation of directly useful knowledge. I did fairly well in high school; in college I tried to excel.

"It might be that I was definitely influenced by my brother who had become a physicist at Cornell University. But at the time I thought I was quite independent in my choice. My reasons were these: First, my college work convinced me that I had a mind that was regarded as analytical. I knew physics demanded that qualification. Second, I realized that many aspects of physics were unexplored, and anyone going into it would never be limited by the narrowness of the field or the limitations of his position. Third, I had continued to be deeply interested in people, and I thought I saw the way in which a physicist might help stabilize young minds in the inevitable drift from creeds and tradition. Fourth, and most importantly, the fundamental nature of physics was particularly appealing. Physics appeared to be on a journey of penetration into the depths of nature. It seemed to be one of the most highly intelligent and fundamentally significant ventures of man. My debate as to a career was between the law, the ministry and physics. The law seemed to be very attractive so far as its practice depended on the use of the mind. Further it promised definite opportunities to assist people and society very directly. But it did not seem to have in prospect that deep and alluring fundamental exploration possible in physics.

The ministry seemed laudable, but in it one would not have the freedom of mind and the constructive opportunity physics seemed to promise. I had no reason to believe that I had any extraordinary gifts in physics. Indeed I felt certain that I would not be satisfied with mere technicality anyway. My professor of physics was a trained cabinet maker, whose scholastic training extended to the master's degree. He was not brilliant nor was he a great scholar. But he had a love for physics. Every spare moment he spent in his shop constructing new pieces of apparatus. This deep love for the subject appealed to me strongly. I knew there was something there for me, also, though doubtless in a different way.

"I can recall no relation of adult performance to juvenile promise. My family was not aware of any constructive talent. Indeed my curiosity more than once caused me to take some balky mechanism apart only to find it too complicated or too difficult to restore. Indeed, my family thought also that I was too impatient for a teacher.

"But physics appealed strongly to me, and I knew I could always use my mind for advancement in that field no matter in what position I found myself. Curiously enough, I did not wish to remain at Cornell University where the young men, I observed, felt they were under some external pressure to do research. I remained two years after taking the degree, accomplished some additional investigations but rather longed to be more 'on my own' where there would be broader demands upon ability. When the chance to go to the University of North Dakota arose, I accepted it, thinking that there where research was not demanded, I would learn whether or not I would carry on investigation as a natural part of any mental life. I reasoned also that education in the Middle West was growing apace and that if I succeeded at North Dakota, I would be called elsewhere in that region. In looking over these steps it seems that my ambition never reached far beyond what seemed a quite possible realization. Thus, with the exception of not being able to get from room one to room twelve in a short time in that public school in Sedalia, Mo., I have never been disappointed by the non-realization of a clearly thought-out ambition. Yet I was not appointed to two positions for which I applied. One was for a teaching position in a high school in Indiana which I sought in my senior year. The other was for a professorship in a New England college which I sought in about 1902. But it appears that in each case failure was probably my good fortune."

Although he always had heavy administrative duties and made many contributions to the science of teaching, he managed to take time enough to make several important research contributions. His earliest work was in radiation, but in 1910 he turned to the field of acoustics. He was one of the very few in the American Physical Society who gave papers on acoustics. Professor Webster of Johns Hopkins University, Professor Miller of Case School of Applied Science, Professor Sabin of Harvard, and Professor Stewart were pioneers in America in this field.

As will be seen from the lists of his paper given at the end of these memoirs he published twenty-seven of them on acoustics from 1903 to 1926. Probably his most significant contribution in this field was the invention of the acoustic filter. He patented some of these filters and sold the rights to use to the Bell Telephone Laboratories. Some of these ideas were used in the construction of telephone microphones and receivers. He did not arrive at these inventions by the experimental method, but by solving the fundamental wave equations for fluids under special boundary conditions. He considered cases where the cross sectional area of tubes suddenly changed, and also the case of tubes with one or more branches. He was able to show that with a proper combination of these he could produce high pass, low pass, or band pass types of filters.

He then turned his attention to X-ray studies of liquids, and between 1926 and 1941 he published thirty papers in this field. His main contribution was to show that liquids in general have a "liquid structure" simulating crystalline structure but not identical to it.

However, he considered research was more an essential and natural activity of the mind than a goal in itself. He was attracted to creativeness, holding technical research as but one of the opportunities of creative activity for the physicist and teacher.

Before Stewart's arrival at the State University of Iowa, only two M. S. and no Ph. D. degrees had been granted there. He stressed graduate work. One year after he arrived, the first Ph. D. in physics was granted. By 1946, about 70 Ph. D. degrees and 150 M. S. degrees had been granted.

Later, his urge to do research work lessened, and he founded the Iowa Colloquium of College Physicists. After retirement this became his main interest. I quote from a biography published in the *Proceedings* of the Iowa Academy of Sciences:

"Into it he put all his energy and drive, striving to make every meeting surpass the preceding ones. Many of the more than one hundred physicists who converged on our campus every June for this meeting were former students of Professor Stewart but all were made to feel his warm welcome and his personal interest in their problems and achievements. He encouraged active participation in the Colloquium by including 'Round Tables' and discussions each year to supplement the formal lectures, and by means of an exhibit consisting of numerous experimental and other devices. An evening was devoted to viewing this exhibit and prizes were awarded as determined by vote of the members of the Colloquium. Although he was hospitalized for six weeks prior to the June 1956 meeting it was held as scheduled and Professor Stewart was present to greet everyone and to 'attend' the meetings by means of a public address system set up in his office. He had moreover nearly completed the program for the 1957 Colloquium at the time of his death."

While a graduate student at Cornell University, Professor Stewart met and became engaged to Zella Mildred White, a medical student in the University. He and "Dr. Zella" were married in 1904. Their forty years of marriage are related with great insight and tenderness in a biography which he prepared after her death in 1943. They had one son, Rodney Cromwell Stewart, who is now a resident of Iowa City.

While Professor Stewart was a tireless worker and got great satisfaction out of keeping occupied, he nevertheless found time to become an enthusiastic golfer and took time off for several extensive tours. The first and longest was a five-month cruise in 1932 with "Dr. Zella," which took them to many countries of the world and from which they returned with a host of pleasant memories and many souvenirs. In the summer of 1935 they visited South America, and in 1938 they took a European tour, visiting France, England, Holland, and the Scandinavian countries. Many visitors in Professor Stewart's home have enjoyed his descriptions of their travels and impressions of other lands.

Professor Stewart took an active part in the organization of the University's interreligious School of Religion and served on its board for twenty-five years. He was President of the board at the time of his death.

At his funeral service, on August 20, 1956, Dr. M. Willard Lampe of this school made the following significant remarks about him which are included in these memoirs:

"In this presence one feels more deeply than he can speak. This is so not merely because of our sorrow as relatives and friends, not merely because of the mystery of death and its sensed relationship to the greater mystery of life, but because, now that our loved one and friend is gone, we are more aware than ever of the richness and fullness of the life he has lived, and also because we are keenly aware of an unpayable indebtedness to him. In my case I realize that I am here and came to this community nearly thirty years ago because, in no small degree, of his influence upon me, and I am also vividly reminded that through the years he has been a source of inspiration and strength—sometimes as an honest critic, sometimes going far out of his way to say a kindly word, always an encourager and friend.

"Of my many associations with him, let me relate only one which

I select as illustrative of the man he was, and of what was central in his life. It was an incident of at least fifteen years ago. One morning shortly after the beginning of a new school year, he telephoned to ask if I would give him two hours at my convenience so that he could tell me of a great discovery he had made during the summer. He said he could summarize this discovery in a short sentence, but he knew it would sound trite to me unless he could give me considerable background. We quickly set a time and he came to my office. This was his story.

"Mrs. Stewart and he had spent the summer on a leisurely ocean voyage around South America, stopping at several ports en route. He had taken no books with him. He had assigned himself no papers to write. No persons or places were the specific object of his visit. There were no problems he wanted to solve—except one, the central problem of any serious mind, viz., what is the most satisfactory philosophy of life? He reviewed this problem in the light of his total experience. He was the son of a Methodist minister. He had done his undergraduate work at DePauw University, a strong Christian institution. He had pursued his special study at Cornell University and then had gone on into his life work as a physicist, all the while retaining his interest in the broad fields of culture, and participating actively in many of the opportunities presented by these fields for personal growth and human service. All of this panorama he had reviewed and contemplated as, day after day, he mused in his steamer chair, or talked with his fellow passengers, or saw the sights of the various ports. He tried to weave it all into the most meaningful pattern, and to make it contribute to some touchstone which he might wholeheartedly accept and follow as a working philosophy of life. Several times during his talk with me that day he stressed the thought that when he stated his conclusion he wanted me to interpret the words far more profoundly than they might appear to me to mean because of any familiarity I might have with them, and I assure you that when he was through, I was prepared so to do. The formula at which he arrived, and for which he became a zealous protagonist and missionary both in spirit and in many active endeavors (although I never could believe that it was anything really new in his life), was this: The most satisfactory philosophy of life is for one to be loyal to the highest and best that one knows. Just that simple and profound!

"After that conference I used to quiz Professor Stewart occasionally on what the phrase 'highest and best' precisely meant to him, what its content was. He did not want to be too specific about it, in fact, its nonspecific character was an essential in his thought, but we who knew him know perfectly well what some of its elements were. One element was his belief in the creative powers which every human being possesses in larger or smaller measure, and the obligation upon each one to use these powers. I have heard him give many a talk, in and out of the university which might well have had as a text the Biblical counsel, 'Stir up the gift of God within you.' Another element in the constituency of his formula was a warm, sparkling friendship that transcended honest differences of opinion, even on important subjects like religion. To this 'highest and best' he was utterly loyal. That is why he was such a bulwark of strength in the interreligious School of Religion from its earliest beginnings. I have just received from Dr. O. D. Foster, a warm friend and admirer of Professor Stewart, and the originator of the idea and essential plan of the School, a letter in which he wrote that at the first conference about the School on this campus, one of the most heartening factors was a talk by Professor Stewart in which he, a noted scientist, enthusiastically approved the project. I have often said—and for this I could cite many a chapter and verse—that Professor Stewart could and did defend the philosophy of the School of Religion better than I, its long-time director, and by defense I mean both intellectually and in practical relationships. There was between him and certain Catholics and Jews in this School a spontaneous, free-wheeling camaraderie, that I have never seen excelled. It was indeed fitting that during the last several months of his life he served as president of the board of trustees of the School.

"Well, our friend, as we say 'is gone.' But I am sure that spiritually he went with a cheery wave of the hand. On returning to Iowa City from a year's absence, I called on him a few weeks ago, and found him his old interested and interesting self, fully prepared as he expressly told me, to meet and take whatever might come. To me he was and is one of God's princely sons who, though gone, lives on forever!"

This is a very fine tribute to this man who had so many interests in life.

One can trace his scientific activity and thought by looking through the list of published papers which is given below.

KEY TO ABBREVIATIONS

Amer. J. Phys. = American Journal of Physics
Chem. Rev. = Chemical Reviews
Ind. J. Phys. = The Indiana Journal of Physics
Iowa Acad. Sci. = Iowa Academy of Sciences
J. Acous. Soc. Amer. = Journal of the Acoustical Society of America
J. Chem. Phys. = Journal of Chemical Physics
J. Gen. Ed. = Journal of General Education
J. Higher Ed. = Journal of Higher Education
J. Opt. Soc. Amer. = Journal of the Optical Society of America
Phys. Rev. = Physical Review
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Rev. Mod. Phys. = Review of Modern Physics
Rev. Sci. Instr. = Review of Scientific Instruments
School Sci. Math. = School Science and Mathematics
Sci. Mo. = Scientific Monthly
Trans. Faraday Soc. = Transactions of the Faraday Society

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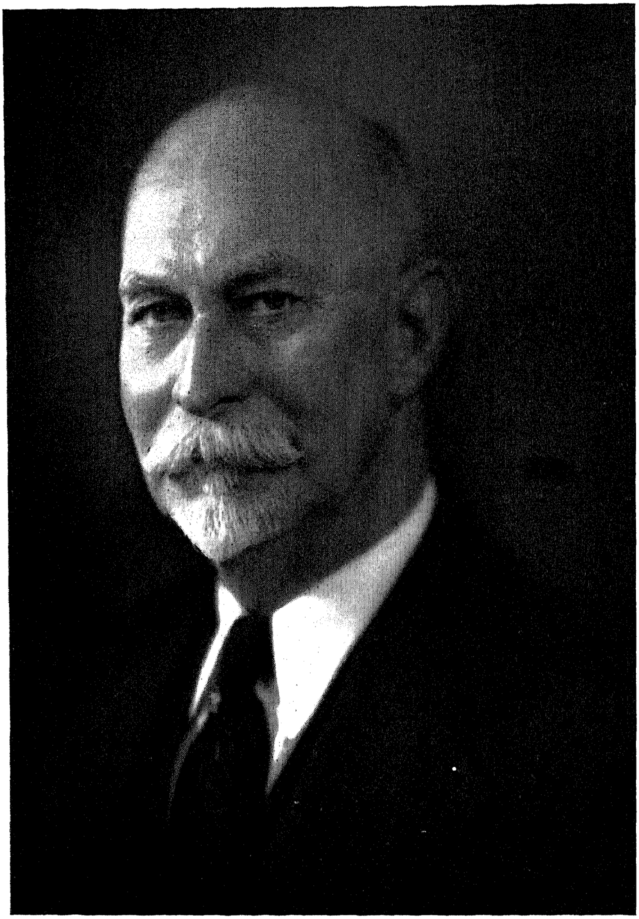

T Wayland Vaughan

THOMAS WAYLAND VAUGHAN

September 20, 1870—January 16, 1952

BY THOMAS G. THOMPSON

A LONG AND DISTINGUISHED lifetime of devotion to science was brought to a close on January 16, 1952, by the passing of the eminent geologist and oceanographer, Thomas Wayland Vaughan.

Born in Jonesville, Texas, on September 20, 1870, Thomas Wayland was one of five children in the Vaughan family. His mother, born Annie R. Hope, was reared and educated in the traditions of the old South. His father was Dr. Samuel Floyd Vaughan, a country physician who, in the course of time, became a land owner of some magnitude. Dr. Samuel Vaughan was an ardent scholar and during his lifetime he assembled one of the finest libraries in his locality. He served as first president of the Harrison County Medical Society and was a member of the Texas Medical Association; the Tri-State Medical Society of Texas, Louisiana, and Arkansas; the American Medical Society, and the Texas Historical Society.

From earliest colonial times until the end of the Civil War, the family belonged to the land- and slave-owning class of southerners, and many of Thomas Wayland Vaughan's forebears were prominent in government or military affairs. Among his ancestors were Thomas Loving (1610–1665), surveyor general of Virginia and a member of the House of Burgesses for James City; John Nevil (1612–1664), who came from England in the "Ark and Dove" in 1634, and who settled in Maryland to become a member of the Council and the Assembly; and Sir Thomas Lunsford (1610–1653), who came to Virginia in 1649. Vaughan's grandfather was a colonel in the Missouri State Militia, and had the distinction of serving twice in the Missouri State Legislature and later, after the Civil War, was twice a member of the Louisiana State Legislature.

Young Vaughan grew up in a home well supplied with excellent books, and he was given the utmost encouragement to read and study. His formal childhood education was in the local public schools in Texas and by private tutor. When he entered Tulane University as a freshman in 1885, Vaughan intended to prepare for the medical profession, but he became interested in the development of the knowledge of electricity and its practical applications and, as a consequence, he graduated in what Tulane at that time called "The Physical Science Course." In his later years Dr. Vaughan was an advocate of the principle of broad undergraduate curricula in preparation for later specialized studies. Illustrative of his own interest in philosophy and literature, as well as in the physical sciences, is the fact that although he received a Bachelor of Science degree in the physical science course, he wrote and read a paper on Oliver Goldsmith at the commencement exercises.

From September, 1889, until June, 1892, Vaughan was an instructor in physics and chemistry at Mount Lebanon, Louisiana, at an institution which would be comparable to a junior college of today. As an undergraduate he had become fascinated by the problems of evolution and the history of the earth, and before he was eighteen he experienced the thrill of making his first discovery of fossils—near his father's home in Texas. While Vaughan was at Mount Lebanon he studied the local flora and fauna, and in 1893 he published his first papers—on the land and fresh-water Mollusca and the trees of northwest Louisiana. It was during his stay at Mount Lebanon that he made his first extensive collection of fossils—the presence of mollusks and corals in a middle Eocene deposit stimulated Vaughan's thinking about the problems of organisms and environment and more particularly about the conditions under which marine organisms and sediments were deposited. In the summer of

1892, he served as an assistant to Dr. Otto Lerch, the State Geologist of Louisiana.

In 1892 Thomas Wayland Vaughan knew without hesitation that he wanted to be a paleontologist. He had taken a course in botany at Harvard in the summer of 1890, and in the autumn of 1892 he returned to Harvard. Feeling that he was weak in biology, he took all the lower division courses in biology, all the courses in paleontology, and several courses in geology. Harvard granted him a Bachelor of Arts degree in 1893 and a Master of Arts degree in 1894. He was registered as a nonresident student at Harvard for several years and in 1903 he received the degree of Doctor of Philosophy, his thesis being a comprehensive account of the Cenozoic corals of the United States, *Eocene and Oligocene Corals of the United States.*

In the years from 1894 to 1903, prior to receiving his doctorate, Wayland Vaughan served the U. S. Geological Survey as assistant geologist. In 1897 he was a delegate to the International Geological Congress in Russia, and was able to devote much time to the study of the collections of corals in European museums. It was during this time in Europe that he studied paleontology under Dr. Ritter J. A. van Zittel, and on this trip he made many lifelong friends, including Sir John Murray, who was of great influence in Vaughan's oceanographic work.

Between 1901 and 1923 Vaughan took part in geological investigations in two large areas, and published more than 100 papers as a result of his findings.

The first of these areas included the West Indies and the Panama Canal Zone. In 1901 Vaughan was a member of a party, under the direction of Dr. C. Willard Hayes, which made a geological reconnaissance of Cuba for the Military Governor, Major General Leonard Wood. Vaughan spent some time during 1911 in the Panama Canal Zone on behalf of the U. S. Geological Survey and the Smithsonian Institution; this work was done partly in cooperation with the Panama Canal Commission. Under the auspices of the Carnegie Institution of Washington in 1914, Vaughan made an expedition to those West Indian islands that lie north of Guadalupe and west of Puerto Rico. From 1919 to 1921 he directed reconnaissance geological surveys of both the Dominican and the Haitian Republics. Most of the expense of these surveys was borne by the governments of the two republics concerned, but the work was done by the U. S. Geological Survey. In 1919, Vaughan made additional geological studies of the Virgin Islands and eastern Puerto Rico for the United States Navy.

The second of these areas included the Atlantic and the Gulf Coast Plains from Cape Cod to the Mexican Border. Investigations were made by the U. S. Geological Survey in cooperation with a number of the State Geological Surveys, with Vaughan in charge of the work from 1907 until 1923. From 1908 to 1915, under the auspices of the Department of Marine Biology of the Carnegie Institution of Washington, Vaughan investigated the corals, coral reefs, and associated phenomena in Florida and the Bahamas, and for a number of years he held the record for having published more papers on corals than any other person.

The work of Wayland Vaughan on corals and coral reefs will be long remembered; he gathered and published much information about existing and fossil reefs, and he was fully aware of the dangers of generalizing on the theory of reef origins. To him, each reef structure was to be studied as a separate entity. Although he contributed no revolutionary ideas on reef origin, his definitive work has been helpful to all students of coral reefs. No one realized more than Vaughan the difficulty in classifying corals, and he once told a student, "If you continue studying corals, you will either become famous or lose your mind!" Vaughan became the unquestioned authority on the Mesozoic, Cenozoic, and Recent corals of the United States, eastern Mexico, the West Indies, and Panama. His contribution in 1907, *The Recent Madreporaria of the Hawaiian Islands and Laysan,* is still the only comprehensive study of the corals of this archipelago, and his 1918 monograph on the Indo-Pacific reef corals is the next landmark after Dana's pioneer work in 1846.

At a comparatively late date, at the age of fifty-four, Dr. Vaughan turned to another major field of endeavor—the study of the Larger Foraminifera. Aware of the difficulties in this field of study, he was modestly conscious of the importance of his own work and that of his students. Some of his friends affectionately recall his comment to the GSA editors, "There's no need to send my manuscripts on Larger Foraminifera to anyone except Storrs Cole; likewise, it's no use to send Cole's manuscripts to anyone except me—no one else would understand them!" Dr. Vaughan not only brilliantly laid the foundation for modern research on the Larger Foraminifera, but also stimulated and trained others to carry on the work.

The third major contribution made to science by this talented worker was in the field of oceanography. Beginning with his studies on the ecology of marine organisms when he was still in his teens, and continuing under the influence of Sir John Murray, Vaughan's interest spread to marine sediments and sedimentary processes and finally to physical and chemical oceanography. He culminated his work in oceanography by serving for twelve years as Director of the Scripps Institution of Oceanography at La Jolla, California, developing the Institution to its present position as an outstanding center of oceanographic research and graduate study. Much of his oceanographic work is intimately connected with his activities with four major committees, on which he served for a considerable period of time.

The first of these committees was the Committee on Sedimentation, formed in 1919 with the assistance of several geological colleagues and organized under the Division of Geology and Geography of the National Research Council. He was chairman of this committee until 1923, when he was succeeded by Professor W. H. Twenhofel of the University of Wisconsin. As a result of the efforts of this committee, not only was a great deal of research on both ancient and modern sediments stimulated, but now courses in sedimentation are given in most of the principal universities of the country. Major contributions of this committee included the preparation of a large volume entitled *Treatise on Sedimentation* by Professor Twenhofel, and a color chart for the description of sediments prepared by M. I. Goldman and others.

Another committee organized under the Division of Geology and Geography of the National Research Council was the Committee on Sound Sounding and Oceanographic Thermographs. Organized in 1922 and changed in 1926 to the Committee on Submarine Configuration and Oceanic Circulation, this committee was disbanded in 1932, but throughout its entire life Vaughan served as its chairman. The reports of this committee became comprehensive accounts of current oceanographic activities throughout the world.

At the third Pan-Pacific Congress, held in Tokyo in 1926, the International Committee on the Oceanography of the Pacific was formed with Dr. Vaughan as its chairman. This committee not only enormously stimulated oceanographic research in the Pacific, but it became a medium whereby the different oceanographic organizations of the Pacific Basin could coordinate their efforts. The record of accomplishments of this committee, between the time of the Pacific Science Congress held in Java in 1929 and that held in Vancouver and Victoria in 1933, has been cited as an example of the usefulness of the Pacific Science Association. Vaughan served as chairman of this committee for ten years.

The fourth committee to which Vaughan gave much of his attention was the Committee on Oceanography in the National Academy of Sciences. This committee was appointed by the President of the Academy in 1927. It originally consisted of Frank R. Lillie as Chairman; William Bowie; E. G. Conklin; B. M. Duggar; J. C. Merriam; and T. W. Vaughan. It was largely through the efforts of this committee that much of the oceanographic work done in the past quarter of a century in the United States was stimulated or brought into being. The Woods Hole Oceanographic Institution and the Oceanographic Laboratories at the University of Washington came into existence as a result of the efforts of this committee, and the Scripps Institution of Oceanography at La Jolla was greatly helped by its activities and recommendations. In 1932 Vaughan was commissioned by this committee to make a tour of the oceanographic institutions around the world in order to prepare a report on the international aspects of oceanography, the purpose of the journey being to supplement information which he had already prepared. Vaughan's report, *The International Aspects of Oceanography,* appeared in book form in 1937 and stressed the importance of international cooperation in oceanographic research. It provided a complete census of existing oceanographic institutions, both those of international character and those of national scope.

In addition, Dr. Vaughan organized in 1940 a subcommittee of the ecology of marine organisms as a part of the Committee on Geological Research of the National Academy of Sciences. Later this became the Committee on Marine Ecology as Related to Paleontology, and one of its major aims was to prepare a treatise on ecology, with emphasis on geological interpretation. Because of his failing eyesight, Dr. Vaughan resigned from the Committee a few months before his death. The Committee published, in two volumes, a *Treatise on Marine Ecology and Paleontology,* as part of the memoir series of the Geological Society of America. Volume 2, *Paleoecology,* was distributed in March, 1957, and Volume 1 later the same year. That the Committee recognized the importance of Vaughan's work is indicated by the dedication of both volumes of the *Treatise* to Dr. Vaughan.

About 1922, prior to the retirement of Dr. W. E. Ritter, who was then director of the Scripps Institution for Biological Research, the administrative officers of the University of California decided to convert the Scripps Institution from biological research to oceanographic research. Vaughan was offered the directorship of the Institution in the spring of 1923, and he accepted and assumed office as Director of the Institution on February 1, 1924. Shortly thereafter the name of the Institution was changed to the Scripps Institution of Oceanography and, largely through the efforts of Vaughan, Scripps has become one of the outstanding oceanographic organizations in the world. Vaughan instituted a program in dynamic and physical oceanography which has been considerably expanded through the years, and he also initiated programs in various aspects of chemical and geological oceanography. The program in biology was continued and augmented. During Vaughan's directorship at Scripps, not only was the oceanographic research expanded, but many additions were made to the physical plant of the Institution.

Dr. Vaughan was a delegate from the United States to the first six Pan-Pacific Science Congresses: Honolulu, 1920; Melbourne and Sydney, Australia, 1923; Japan, 1926; Java, 1929; Vancouver and Victoria, 1933; and San Francisco, 1936. Among his active associations were: Delta Tau Delta; National Academy of Sciences; Sigma Xi; American Academy of Arts and Sciences (fellow); American Philosophical Society; American Association for Advancement of Sciences (president, Pacific division 1930–31); Geological Society of America (president, Cordilleran section, 1923, president, 1939); Association of American Geographers; Paleontological Society (president, 1923); American Meteorological Society (fellow); California Academy of Sciences; San Diego Natural History Society (president, 1925); Seismological Society of America; American Geophysical Union (chairman, Section on oceanography, 1926–28); Geological Society of Washington (president, 1915); Ecological Society; Society for Experimental Biology and Medicine; Academy of Natural Sciences of Philadelphia; Italian Royal Geographical Society; Royal Science Society in the Netherlands Indies; Zoological Society of London; Linnean Society (foreign member); Geological Society of London.

During the course of his busy and productive career, Wayland Vaughan found satisfaction in pursuing at least three avocations—the study of comparative religions, of old Teutonic legends, and of oriental art. He became so fond of Japanese customs and art that in his sixties he mastered the Japanese language and was in much demand as a lecturer on oriental art. In 1933, Emperor Hirohito honored him in private audience and presented him with a beautiful cloisonné vase as a token of the love and esteem for Dr. Vaughan in the hearts of Japanese scientists.

In 1936, at the time of his automatic retirement as Director of the Scripps Institution at the age of sixty-five, Dr. Vaughan chose to resume his paleontological studies at the U. S. National Museum in Washington. Here he pursued his systematic research on the Larger Foraminifera and other studies.

After a severe attack of pneumonia in 1947, the eyesight of this outstanding scientist became permanently impaired. The partial blindness ended his own scientific work, but he retained a keen interest in the scientific work of others, and in the workers themselves. During this difficult time of adjusting to a life in which he was unable to read or study, Dr. Vaughan arranged to listen for two or more hours each day to friends and students who read to him the scientific literature which he himself had done so much to enrich. He had a phenomenal memory and thus was able to keep in touch with his special fields of interest.

Dr. Vaughan was a man of average stature, about five feet nine inches in height, and weighed about 160 pounds. In his younger days his hair was dark, but before he was thirty he was bald. His keen eyes were gray-blue, and he affected a beard, reddish-brown in his younger days, but white as he became older. He was characterized by a certain brusqueness of manner which never concealed his innate good humor and sociable nature. Vaughan was strong-willed, but he was always open to evidence suggesting that his often strong opinions might be changed. A meticulous worker himself, he set great store on accuracy in all things. He was known for his ruthless criticism of manuscripts and never hesitated to express himself forcefully. Many of his fellow workers will remember the apprehension with which they awaited his comments on a manuscript—many papers had to be completely rewritten to meet his exacting standards, and great was an author's pleasure when a paper received Dr. Vaughan's approval.

A famous host, Wayland Vaughan thoroughly enjoyed social occasions and the company of his friends. Even after his partial blindness, he attended special affairs at the Cosmos Club and the National Academy of Sciences.

Mrs. Vaughan, nee Dorothy Quincy Upham, shared her husband's rich and active life from the time of their marriage in 1909 to her sudden death in 1949. Their daughter, Caroline Ely, became Mrs. James H. Fortune, Jr.

Wayland Vaughan was a prodigious worker, and his talents were such that he was able to publish nearly four hundred titles, many of outstanding importance. This he did while carrying on his administrative work with distinction, and while his versatile mind found interest in his avocations and in community and international affairs. He was the organizing secretary of the National Society of Fine Arts in Washington, D. C., and he was a founder and charter member of the American Federation of Arts.

Such a man rightfully received many honors, among them the Agassiz Medal for oceanography, and the Mary Clark Thompson medal for geology and paleontology, both awarded by the National Academy of Sciences; and the Penrose Medal of the Geological Society of America. The Japanese Government awarded him the Order of the Rising Sun, Third Class. The Universities of California and British Columbia honored him by conferring LL. D. degrees, and Tulane University awarded an honorary D. Sc. to its distinguished alumnus in 1944. A final honor in the closing year of his life was a symbol of the impact of his life on the development of modern oceanography—with impressive ceremonies, the Scripps Institution dedicated its newest and finest building to Thomas Wayland Vaughan.

Vaughan's long life of accomplishment is an example of the dedication of a brilliant and versatile mind to science in its broadest aspect. In oceanography, in geology, in paleontology, his death on January 16, 1952, left a gap not soon to be filled. Almost sixty of his eighty-one years were devoted to a career of inspired research, and one of his major accomplishments was his foresight in training others to carry on work that he had started. Throughout his career he not only did a great deal of work with others, but he had the ability to stimulate others to do work in which he took no direct part.

No memorial can do justice to the outstanding scientific accomplishment and tremendous productivity of Dr. Vaughan. Perhaps the most fitting summary of his philosophy was a statement in his speech of acceptance at the presentation of the Penrose Medal in 1946. President Bowen of the Geological Society of America had made the statement, "Thomas Wayland Vaughan: Student of the sea; you have plumbed its depths; you have conned its shallows and its flats; especially you have observed the living beings that dwell in its quiet expanses, or again, near its rocky shores. You have projected your findings into the past and have thus been able to write for us the story of ancient seas and their denizens . . . in a splendid chronicle." Dr. Vaughan's own humble words of reply ring out as a challenge to those who follow: "To have helped is the most that any one may hope for—the work has barely begun!"

KEY TO ABBREVIATIONS

Acad. Nat. Sci. Phila. Proc. = Academy of Natural Sciences of Philadelphia Proceedings
Ala. Geol. Surv. Bull. = Alabama Geological Survey Bulletin
Amer. Assoc. Adv. Sci. = American Association for the Advancement of Science
Amer. Assoc. Petrol. Geol. Bull. = American Association of Petroleum Geologists Bulletin
Amer. Geogr. Soc. Bull. = American Geographical Society Bulletin
Amer. Geol. = American Geologist
Amer. Geophys. Union Trans. = American Geophysical Union Transactions
Amer. Jour. Sci. = American Journal of Science
Amer. Meteor. Soc. Bull. = American Meteorological Society Bulletin
Amer. Nat. = American Naturalist
Ann. Mag. Nat. Hist. = Annals and Magazine of Natural History
Assoc. d'Océanogr. Phys. = Association d'Océanographie Physique
Assoc. Amer. Geogr. Ann. = Association of American Geographers Annals
Biol. Soc. Wash. Proc. = Biological Society of Washington Proceedings
Bur. Econ. Geol. Texas = Bureau of Economic Geology of Texas
Calif. Acad. Sci. Mem. = California Academy of Sciences Memoirs
Calif. Jour. Develop. = California Journal of Development
Calif. Mo. = California Monthly
Carnegie Inst. Wash. Publ. = Carnegie Institution of Washington Publications
Carnegie Inst. Wash. Year Book = Carnegie Institution of Washington Year Book
Cong. Geol. Internat. Comptes Rend. = Congrès Geologiqué International Comptes Rendus
Div. Geol. Geogr. Nat. Res. Counc. = Division of Geology and Geography of the National Research Council
Ecol. Mon. = Ecological Monographs
Eng. Min. Jour. = Engineering and Mining Journal
Fla. Geol. Surv. Ann. Rept. = Florida Geological Survey Annual Report
Geogr. Rev. = Geographical Review
Geol. Mag. = Geological Magazine
Geol. Soc. Amer. Bull. = Geological Society of America Bulletin
Geol. Surv. Ga. Bull. = Geological Survey of Georgia Bulletin
Johns Hopkins Univ. Circ. = Johns Hopkins University Circular
Jour. Geol. = Journal of Geology
Jour. Paleon. = Journal of Paleontology
Md. Geol. Surv. = Maryland Geological Survey
Mem. Nat. Acad. Sci. = Memoirs of the National Academy of Sciences
Mus. Comp. Zool. Bull. = Museum of Comparative Zoology of Harvard University Bulletin

Nat. Res. Counc. Bull. = National Research Council Bulletin
New Zealand Inst. Trans. = New Zealand Institute Transactions
Pac. Sci. Cong. = Pacific Science Congress
Pan-Pac. Sci. Conf. Proc. = Pan-Pacific Scientific Conference Proceedings
Phila. Acad. Nat. Sci. Proc. = Philadelphia Academy of Natural Sciences Proceedings
Pop. Sci. Mo. = Popular Science Monthly
Proc. Internat. Zool. Cong. = Proceedings of the International Zoological Congress
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Quart. Jour. Geol. Soc. = Quarterly Journal of the Geological Society
Sci. Mo. = Scientific Monthly
Smithsonian Inst. Ann. Rept. = Smithsonian Institution Annual Report
Smithsonian Inst. Misc. Coll. = Smithsonian Institution Miscellaneous Collections
Southern Med. Jour. = Southern Medical Journal
U. S. Fish Comm. Bull. = United States Fish Commission Bulletin
U. S. Geol. Surv. Ann. Rept. = United States Geological Survey Annual Report
U. S. Geol. Surv. Bull. = United States Geological Survey Bulletin
U. S. Geol. Surv. Prof. Papers = United States Geological Survey Professional Papers
U. S. Nat. Mus. Bull. = United States National Museum Bulletin
U. S. Nat. Mus. Proc. = United States National Museum Proceedings
U. S. Naval Med. Bull. = United States Naval Medical Bulletin
Univ. Calif. Publ. Dept. Geol. Bull. = University of California Publications, Department of Geology Bulletin
Verhandl. Ozeanogeographischen Konferenz, gesellsch. Erdk. Berlin = Verhandlungen der Ozeanogeographischen Konferenz, Gesellschaft für Erdkunde
Wash. Acad. Sci. Jour. = Washington Academy of Sciences Journal

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JOHN VON NEUMANN

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BY S. BOCHNER

JOHN VON NEUMANN's academic career was in mathematics, even though he was very much associated with theoretical physics and to an extent with theoretical economics. He began his career in earnest with axiomatic set theory and logic and pursued this topic actively for several years. In the closing years of his life, while busily filling many positions as scientific executive on a national level, he was laying plans for a treatise in the "logics" underlying the mathematical foundations of games and strategies with applications to economics, of the theory of codifying instructions to computing machines, and of the theory of networks both electrical and nervous. The activities mentioned did not complete his professional life by any means. But in a sense they were very characteristic of the man and his basic style.

The contemporary mathematical activities we have just enumerated, in which von Neumann so excelled, whatever their implications for mid-century's modern man and whatever their fascination for the philosopher in search of modernity, are not yet too well established with the old-line mathematician, and the density of their mathematical content is as yet not always deemed to be optimal. In fact, von Neumann's mathematician's mathematics was of stronger texture by its very nature, and his prowess in theoretical physics also had to maintain itself rather more competitively. But his lifelong commitment to questions of logics, axiomatization, and formalization was expressive of his mathematical personality, nonetheless.

John von Neumann

In his more traditional achievements he had his peers, and in his work in theoretical physics he did not originate a basic verity as several of his contemporaries in the 1920s did. But if to his preponderance in mathematics and physics, and his familiarity with many other problems of science, one adds his momentous excursion into the theory of rational behavior—as the implications of games and strategies are named by some—then it can be said that, among mathematicians at any rate, he was an exceptional contemporary indeed. By intellectual faculty he was a mathematician, but by species he was a scientific man within all the major connotations of today, from esoteric ones to those of popular appeal.

His effectiveness was largely due to his ever-present mental manipulatory quickness. He could literally "think on his feet," and much of his best work may have received its initial impulse in just this way. He had a prodigious memory, and legend has it that he knew all the facts and dates from many volumes of standard histories by heart.

Apart from achievements in the areas enumerated above, the high points of his work are as follows: (1) the extension of operators in Hilbert space from bounded to unbounded ones (# 30 of the Bibliography), (2) almost periodic functions on groups (# 52), and (3) his masterwork, algebras of bounded operators in Hilbert space (beginning with # 62). To these one might add (4) his definition of a "state" in quantum theory as an element in a Hilbert space (beginning with # 9) and (5) the introduction of analytic parameters in a locally Euclidean group in the compact case (# 48).

1. His theory of non-bounded operators in Hilbert space was arresting. The naturalness with which he axiomatized the Hilbert space and introduced concepts like maximal operator, hypermaximal operator, deficiency of an operator, etc., was breathtaking to specialist and nonspecialist alike. And yet there was nothing greatly contrived in the analysis, nor was there anything that some of the other mathematicians who were familiar with the topic could not have really done. As a matter of fact, Frederic Riesz, who had known the theory

as well as anybody, after catching his breath wrote a comment on the new theory, in the introduction to which he asks himself somewhat plaintively what he, Frederic Riesz, had been doing with himself all these years.

2. His theory of almost periodic functions on groups was glamorous. It soon turned out that syllogistically the theory can be put together much more simply than von Neumann had done it. But the effect of the theory, especially on the so-called Abstract Harmonic Analysis which was soon to emerge, was a decisive one, and he fully deserved obtaining the Bôcher prize for it.

3. The theory of algebras of operators, written in important phases in collaboration with F. J. Murray, has not the ease and naturalness of much of his earlier work and it is somewhat heavy in the manner of composition, but in strength, tenacity, and importance it is not outdone by anything in its generation. Any representation of a group by bounded operators (in an infinitely dimensional space) can be enlarged to such a representation of the enveloping group algebra and thus subsumes under the Murray-von Neumann theory. Now it is a fact that the theory of representations in the particular case of a group algebra has been and continues to be strongly guided by the more general theory, and in certain parts must still rely on taking over results directly from it.

4. Dr. von Neumann's papers in the 1920s on the foundations of quantum mechanics and their effect on thermodynamics were extremely mature. His formal definition of a physical "state" as being a point in a Hilbert space representing the system was as readily accepted by physicists as if it had been the most obvious thing since creation, and this concept of a "state" has had some repercussions in a purely mathematical context as well.

5. His solution of "Hilbert's fifth problem" in the compact case had no bearing on the subsequent solution by others in the non-compact case, but it is nonetheless interesting as an achievement of von Neumann's. He shows in it his mastery of finite linear representations, and he employs in it the group invariant measure which had

just been found by Haar. It is somewhat surprising that von Neumann did not construct the group invariant measure himself, since measure theory, as a bridge between Boolean algebras and linear functionals on vector spaces, was very close to his thinking. But at any rate, soon after this measure had been introduced, he studied it extensively and contributed much to its propagation.

Dr. von Neumann also attached major standing to his work on the ergodic theorem, 1931–32 (#41). On one occasion, he listed his essential work under the following three headings: the papers on quantum mechanics in the 1920s; his total work in operator theory, 1930–39; his version of the ergodic theorem.

Most of von Neumann's published work involves in a decisive phase linear spaces, finite or infinitely dimensional ones, or functionals and linear operations between such. The approach via linear spaces covers, or can be made to cover, a large part of the total mathematical area nowadays. Still, an important part of the landscape is not included in it. It leaves out almost anything which involves "geometry" in a proper global sense, such as topology, differential geometry and harmonic integrals, general relativity globally, algebraic geometry, etc. Into this kind of mathematics von Neumann ventured rarely, if at all, and he actually had no affinity with it in his thinking. An incident in his work may illustrate this. In 1929 he published the important result (# 24) that a group of linear transformations in a finite dimensional space, if closed, is a Lie group. Élie Cartan, who was a geometer, immediately recognized that the theorem is a special case of the general proposition that a closed subgroup of a Lie group is again a Lie group, and he proved it by the same procedure, although in an abbreviated form. There is hardly a young mathematician today who realizes that this familiar general proposition was von Neumann's discovery originally.

The various parts of mathematics which involved geometry have of late been tending to coalesce into one, and thus to restratify the classical traditional body of mathematics into a new pattern. This is a significant development, and to a historical observer it would almost appear as if this mathematics were harking back to its Pythagorean origin, when all mathematics was geometry and "structure" in dissoluble union, by deliberate design, and less naively so than is sometimes assumed. On the other hand, the mathematics of logical and operational approach, to which von Neumann was gravitating by natural disposition, is also aware of its origin genetically, but in a rather more negating manner on the whole, and in a much more consciously modern and even antagonistic spirit. Many a chapter in mathematical logic or semantics is like a page from Aristotle's *Organon* or *Rhetoric,* but with all sentences crossed out and each replaced by an entirely different one on the margin.

In short, there are two trends of modernism discernible in mathematics today. One is incisive, emphatic, frequently stirring, and always provocative. The other is a kind of regeneration with an element of traditionalism operating as a positive motive power in it. Von Neumann did not share in the latter.

John von Neumann always had the natural air of someone who had been reared from childhood in material comfort. He was born on December 28, 1903, in Budapest, Hungary, the eldest of three sons, and first came to the United States when he was twenty-seven years old. His brothers and his widowed mother also came here, and his mother died during von Neumann's illness, only six months before his death. His father, Max von Neumann, was a banker. First manager and later vice-president of a major bank, he finally was made one of the partners of a private banking firm, all in Budapest. According to John, it was his father who encouraged him to choose a career in science. John showed a pronounced interest in mathematics from the age of thirteen. He was also a great reader of books on history throughout his life, and in both science and history his retentive memory was most remarkable.

He attended grammar school and high school in Budapest. As a youth he had no bent towards physical or sporting activities. And even when later on he drove some very dashing looking cars with the maximum velocity for which they were designed, he never acquired the mien of a "sporting type." He did claim, however, that he had once learned to ride a bicycle, but admitted that a pair of trousers was part of the "tuition price." In his teens he was somewhat gauche and not quite the type of "leader." But there was nothing awkward about his manner in later life, and he gave the impression of considerable collectedness and self-confidence. He was courteous and could be quite jovial. In company he was an excellent raconteur. He never smoked, and would drink but rarely, although he would sometime simulate gaiety as if he had imbibed.

Even before entering on college studies, he was co-author of a paper (# 1 of the biblography) at the age of eighteen. He studied two years at the University of Berlin, 1921–23, and also took courses in chemistry. Fritz Haber, the then academic leader of chemistry in Germany, soon met him, and is reported to have said to friends that he expected or wished that von Neumann would take up chemistry as a career. John went from Berlin to the Institute of Technology in Zürich, Switzerland, where Hermann Weyl was in the mathematics department at the time. He left the Institute in 1925 with an engineering degree in chemistry. In the meantime, he had begun publishing very good mathematical papers pertaining to axiomatic set theory, and in 1926 he was awarded a doctorate for such a thesis at the University of Budapest. This enabled him to secure immediately a position as Privatdozent at the University of Berlin. One of the ranking mathematicians there was Erhard Schmidt, known mainly for his work in integral equations, who also had a strong interest in set theory, fostered by a lifelong friendship with Ernst Zermelo, of "Zermelo-axiom" fame.

John's interest soon turned to the recently created quantum theory, which was produced, packaged, and delivered by several "youngsters" in their twenties, barely older than himself. He began to think through the mathematical scheme of the theory in his own terms and, in the process, learned theoretical physics, and readied mathematical tools for future use. He wrote some lengthy articles on quantum theory, and there are indications in the first ones that it was Max Born's statistical interpretation of the Schroedinger wave function and also Born's attempt at rigorization of approach that put von Neumann initially on the track of becoming one of the busiest and most sought-after scientific consultants to military and other organizations in this country.

In 1928, between papers on mathematical logic and his first papers in physics, he "squeezed in" his first and basic paper on the theory of games. There had been forerunners in the field (E. Zermelo, H. Borel, and H. Steinhaus, among others) by whom most of the concepts like play and counterplay, chance and deception, pure strategy and mixed strategy had been anticipated in one form or another. But von Neumann brought the results of others and his own new ones together, clearly and axiomatically, into twenty-five pages. In the briefest of footnotes he made reference to the analogy with some problems in economics, and in another footnote, added in proof, he made reference to a very recent note of Borel's in which for the two-person zero-sum game the underlying minimax theorem was proposed, although not proven, as in von Neumann's paper. Eventually the paper grew into the treatise with Oscar Morgenstern published by the Princeton University Press in 1944 (# 90). When deciding to print the book, the Press was cheerfully resigned, for the sake of scholarship, to face the financial deficit they expected. But, in fact, they had to reprint the book in 1947 and again in 1953.

The quantum theory led von Neumann naturally to a re-examination of the theory of operators in Hilbert space and, while still in Berlin, he published in 1929 his paper # 30 on unbounded operators. It was soon followed by his paper # 31 on algebras of operators, the first in that direction. He discussed this material with Erhard Schmidt, who had some influence on clarifying the distinction between maximal (symmetric) and hypermaximal (selfadjoint) operators. This last work won for him the admiration of mathematicians. In 1929 he transferred to the University of Hamburg as Privatdozent, but remained only one year. In 1930 he came to Princeton, N. J., which remained his academic address afterwards.

About that time the Springer publishing firm solicited him to write for their so-called Yellow Collection (this was not the official name) a volume on the mathematical foundations of quantum mechanics (# 47a). While negotiations for the book were still in progress, von Neumann became dissatisfied with the galley proofs of an article in print, and wanted to make very costly revisions in it. The journal in which the article was to be published was also controlled by Springer, and in order to humor him they let him make the revisions without charge.

Just before coming to Princeton in 1930, von Neumann married Marietta Kovesi in Budapest. They were divorced in 1937, shortly after their daughter Marina was born. She is his only child, and has been Mrs. Robert Whitman since June 1956. In 1938, von Neumann married Klara Dan, also originally from Budapest, who later worked on his Computer Project.

From 1930 until 1933 he was Visiting Professor at Princeton University, and in 1933 became a permanent member of the Institute for Advanced Study, which academic post he held till his death. He soon became widely known to mathematicians in this country, at first chiefly to senior ones, but after his paper on almost periodic functions (# 55) to the "rank-and-file" as well. Until 1940, when the war began to change the pattern of his activities, he gave lecture courses fairly regularly, and he had large audiences. Furthermore, his papers were written in a uniform orderly style and were accessible for study by younger research workers, even though the subject was a difficult one.

In 1935, when F. J. Murray was a National Research Fellow in residence at the Institute for Advanced Study, von Neumann began the study of algebras of operators in earnest. Several of the papers were written in collaboration (# 62, # 70, # 87) with Murray, and Murray's partnership was not a nominal one. There were many discussions between them with a brisk give-and-take throughout. An offshoot of these studies was von Neumann's "continuous geometries." They are typified by a kind of projective space in which the hierarchy of linear subspaces of increasing dimension is no longer specified by discrete dimension numbers (that is, integer numbers, or multiples of integer numbers with some common factor) but by continuous real numbers out of an entire interval. This was the topic of his Colloquium Lectures before the American Mathematical Society in 1937. He did not publish the lectures, as most lecturers do, but several sets of notes found among his papers, written as always in his legible round hand, may have been intended to be used for this purpose.

Dr. von Neumann was elected to the National Academy of Sciences in 1937.

After completing the book with Morgenstern in 1944, von Neumann's attention turned to computing machines and, somewhat surprisingly, he decided to build his own. As the years progressed, he appeared to thrive on the multitudinousness of his tasks. It has been stated that von Neumann's electronic computer hastened the hydrogen bomb explosion of November 1, 1952.

When the war came, von Neumann was called to serve on an increasing number of upper echelon boards and committees concerned with armament programs or the utilization of nuclear energy. As most of the research work involved was classified, it is not easy to assay what kind of original work he did. But all published citations which he received are unanimous and convincing in praising him for outstanding contributions in many areas of vital importance.

In the summer of 1955, only a few months after his appointment to the Atomic Energy Commission had been approved by the Senate, he became ill. Cancer was soon suspected, but he continued to work fairly regularly for several more months. His last public appearance was early in 1956 when, in a wheelchair at the White House, he received the Medal of Freedom from President Eisenhower. About that time it began to be known that he was not expected to recover. In April, 1956, he was taken to the Walter Reed Hospital, where he remained till the end. He lingered on longer than was expected, dying on February 8, 1957.

Von Neumann was baptized a Roman Catholic in 1930, and he died in the faith. He is buried in Princeton, N. J.

CHRONOLOGY

1903	Born, Budapest, Hungary, December 28.
1930–33	Visiting Professor, Princeton University.
1933–57	Professor of Mathematics, Institute for Advanced Study, Princeton, N. J.
1937	Gibbs Lecturer, Colloquium Lecturer, Bôcher Prize, all in American Mathematical Society.
1940–57	Scientific Advisory Committee, Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland.
1941–55	Navy Bureau of Ordnance, Washington, D. C.
1943–55	Los Alamos Scientific Laboratory (AEC), Los Alamos, N. M.
1945–57	Director of Electronic Computer Project, Institute for Advanced Study, Princeton, N. J.
1947	D. Sc. (hon.), Princeton University; Medal for Merit (Presidential Award); Distinguished Civilian Service Award, U. S. Navy.
1947–55	Naval Ordnance Laboratory, Silver Spring, Maryland.
1949–53	Research and Development Board, Washington, D. C.
1949–54	Oak Ridge National Laboratory, Oak Ridge, Tennessee.
1950	D. Sc. (hon.), University of Pennsylvania and Harvard University.
1950–55	Armed Forces Special Weapons Project, Washington, D. C.; Weapons System Evaluation Group, Washington, D. C.
1950–57	Member Board of Advisors, Universidad de los Andes, Colombia, South America.
1951–53	President, American Mathematical Society.
1951–57	Scientific Advisory Board, U. S. Air Force, Washington, D. C.
1952	D. Sc. (hon.), University of Instanbul, Case Institute of Technology, and University of Maryland.
1952–54	Member, General Advisory Committee, U. S. Atomic Energy Commission, Washington, D. C. (Presidential appointment).
1953	D. Sc. (hon.), Institute of Polytechnics, Munich; Vanuxem Lecturer, Princeton University.
1953–57	Technical Advisory Panel on Atomic Energy, Washington, D. C.
1955–57	U. S. Atomic Energy Commissioner (Presidential appointment).
1956	Medal of Freedom (Presidential award); Albert Einstein Commemorative Award; Enrico Fermi Award.
1957	Died, Washington, D. C., February 8.

Academy memberships:

Academia Nacional de Ciencias Exactas, Lima, Peru.
Academia Nazionale dei Lincei, Rome, Italy.
American Academy of Arts and Sciences.
American Philosophical Society.
Instituto Lombardo di Scienze e Lettere, Milan, Italy.
National Academy of Sciences.
Royal Netherlands Academy of Sciences and Letters, Amsterdam, Netherlands.

KEY TO ABBREVIATIONS

Acta Szeged. = Szeged. Egyetem. Acta universitatis szegediensis. Acta scientarum mathematicarum.
A. M. S. Bull. = American Mathematical Society Bulletin
A. M. S. Trans. = American Mathematical Society Transactions
Ann. Math. = Annals of Mathematics
Ann. Math. Stat. = Annals of Mathematical Statistics
Ann. Math. Studies = Annals of Mathematics Studies
Astrophys. J. = Astrophysical Journal
Commun. Pure Appl. Math. = Communications on Pure and Applied Mathematics
Compos. Math. = Compositio Mathematica
Erg. eines Math. Coll. = Ergebnisse eines mathematischen Kolloquiums
Fund. Math. = Fundamenta Mathematicae
Gött. Nach. = Gesellschaft der Wissenschaften zu Göttingen Nachrichten. Mathematisch-physikalische Klasse.
Hamb. Abh. = Hamburg Abhandlungen
Jahresb. = Deutsche Mathematiker-Vereinigung, Leipzig, Jahresbericht
J. Appl. Phys. = Journal of Applied Physics
J. f. Math = Journal für Mathematik
Math. Ann. = Mathematische Annalen
Math. Nach. = Mathematische Nachrichten
Math. Tables and Other Aids to Comp. = Mathematical Tables and Other Aids to Computation
Math. Zschr. = Mathematische Zeitschrift
Math. Phys. Lapok = Mathematikaies physikai Lapok
Math. Sbornik = Matica slovenska, Turócz-Szent-Márton. Sbornik.
N. A. S. Proc. = National Academy of Sciences Proceedings
Nat. Bur. Standards Appl. Math. Series = National Bureau of Standards Applied Mathematics Series
Phys. Zschr. = Physikalische Zeitschrift
Portugaliae Math. = Portugaliae Mathematica
Proc. Comp. Sem. = Proceedings, Comptroller's Seminar
Rev. Econ. Studies = Review of Economic Studies
Sitzungsber. d. Preuss. Akad. = Sitzungsberichte der Preussischen Akademie
Tomsk. Univ. Rev. = Tomsk Universitet Review
Zschr. f. Phys. = Zeitschrift für Physik

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